University of Reading

The behaviour and welfare of goat kids during the milk feeding stage and weaning transition

Thesis submitted in the fulfillment of the degree Doctor of Philosophy

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Declaration of original authorship

I confirm that this thesis is my own work and that the use of all material from other sources has been properly and fully acknowledged.

Holly M. Vickery

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Abstract

With a lack of goat-kid specific research, this thesis aimed to investigate the behaviour, productivity, and individuality of artificially reared goat kids during the milk feeding period and weaning transition, to recommend how on-farm management could be improved for the benefit of kid welfare. The first two studies collected survey data from farmers. The first established variation in management likely reflecting differing system needs relating to scale and milk feeding system; farms rearing >100 kids were more likely to ad libitum milk feed (P<0.001) and kids were more likely to be abruptly weaned from these systems (P≤ 0.001). The second reported farmers are unwilling to change practices due to kid health and feasibility concerns. The subsequent animal research was tailored towards commercial management, to address farmer concerns. The third study quantified how kids feed from ad libitum milk systems and found individual variation in milk feeding behaviour (intake range: 1.4-2.7 L/day; daily rewarded milk station visits: 2-19) together with concerningly low solid feed intakes (64 g/d of creep feed) before the industry standard practice of abrupt weaning, which likely affects welfare. The fourth study investigated a commercially feasible gradual weaning method for ad libitum systems, and successfully addressed farmers' concerns. It found that milk intake was reduced (P<0.001); there were growth benefits (second weaning period: gradually weaned kids had higher gains P=0.046) and in the first (P=0.022) and second weaning periods (P<0.001) gradually weaned kids had higher creep intakes. The final study investigated methods to assess individuality and identified three consistent behaviours ('stand still-look' – familiar person tests; 'latency until contact' – novel object tests; 'bipedal stance' – both tests) that could be indicative of personality. This thesis fills key gaps in our knowledge of artificially reared goat kids and establishes a species-specific baseline for tailoring management and research in the future.

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List of abbreviations

ADG: Average Daily Gain

AIC: Akaike Information Criterion

AW: Abrupt Weaning

AWIN: Animal Welfare Indicators Project

CP: Crude Protein

DEFRA: Department for Environment, Food and Rural Affairs

DM: Dry Matter

EMM: Estimated Marginal Mean

EU: European Union

FP: Familiar Person

GB: Great Britain

GLM: General Linear Model

GLMM: General Linear Mixed Model

GW1: Gradual Weaning 1

GW2: Gradual Weaning 2

ICC: IntraClass Correlation Coefficient

MH: Modified Home

MI: Milk Intake

NO: Novel Object

NZ: New Zealand

SE: Standard Error

UK: United Kingdom

USA: United States of America

UT: Unfamiliar Testing

1. General introduction

1.1 Introduction

Small ruminants have significant global importance and have been utilised by humans since at least 2500 B.C. (Dubeuf and Boyazoglu, 2009; Galal, 2005) within a wide variety of production systems. Since their domestication around ten thousand years ago (Zeder and Hesse, 2000), goats have become popular around the globe with an estimated population of over 1.1 billion in 2021 (FAOSTAT, 2023). Often colloquially referred to as the 'poor man's cow', goats are renowned for their versatility, short gestation periods with multiple kids per birth (Peaker, 1978), and large range of environmental and dietary tolerances (reviewed by Nair et al., (2021). Within Great Britain (GB; England, Scotland and Wales) the registered goat population has seen a remarkable increase over a ten-year period, whereas during the same period the cattle population has decreased, and the sheep population has remained consistent (Figure 1-1). These statistics show that whilst the population of other farmed species in GB appear to have plateaued, goat farming is an emerging new industry that is continuing to grow.

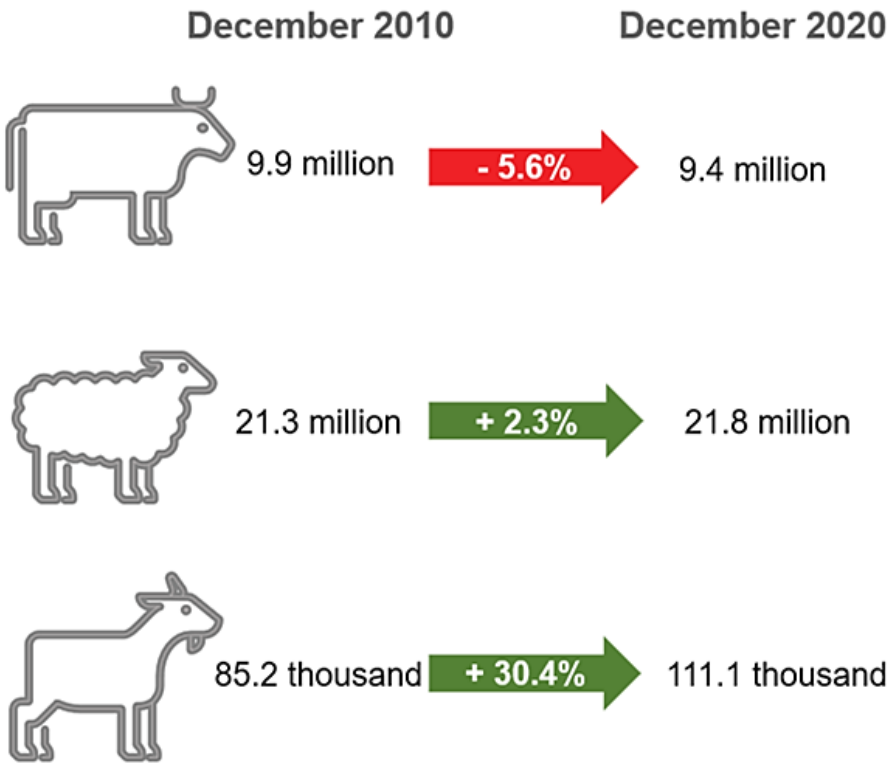

Figure 1-1. Population changes of registered livestock individuals over a ten-year period in Great Britain (England, Scotland and Wales) (APHA, 2021).

Whilst goats are farmed for meat, milk, and fibre, due to the size and intensive practices of the dairy-goat milking industry, and the likely impacts on animal behaviour and welfare, this thesis will focus on this sector. Smaller than cows, goats require fewer inputs and have a higher adaptability to a much wider range of climatic conditions than any other milk-producing domestic animal (reviewed by Koluman Darcan and Silanikove, 2018). Furthermore their milk appears to have superior nutritional qualities than cow's milk (for a comprehensive review see Haenlein, 2004). The global goat milk products market is increasing and is currently valued at $17.95 billion, with a compound annual growth rate prediction of 7.7% from 2022-2027 (Arizton, 2022) and cheese being the most popular product (44.5% of market revenue, Arizton, 2022). After cows and sheep, goats are the third most popular species for milk production in Europe (Dubeuf et al., 2010). Dairy goat farming is an important agricultural sector within the European economy, (de Rancourt et al., 2006; Dubeuf et al., 2010), and despite only owning 1.4% of the world goat herd in 2021, Europe produced 15% of the world's goat milk (FAOSTAT, 2023), and held a 31.4% share of the global goat milk market (Arizton, 2022), indicating the intensive nature of the industry and husbandry practices (Figure 1-2).

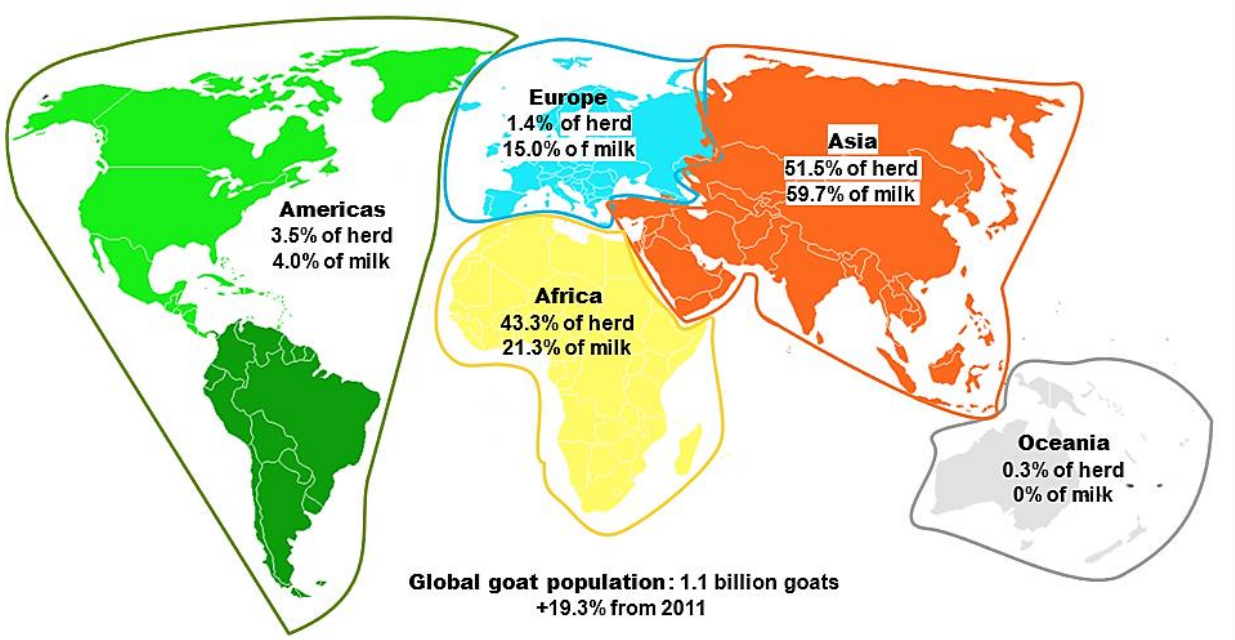

Figure 1-2. 2021 Share of global goat population and milk production by continent (FAOSTAT, 2023).

There has been increasing focus on livestock industries' contributions towards climate change, and as evidence shows that goats emit less methane than other livestock species (for an overview see Koluman Darcan and Silanikove, 2018), have high adaptability to climatic conditions (physiological review, Silanikove, 2000; general overview Nair et al., 2021), and have more efficient conversion of inputs into milk (Table 1-1) than cattle goats are likely to continue to grow in global popularity.

Table 1-1. A comparison of cattle and goat Dry Matter (DM) intake, water intake, and CO_2 (Carbon dioxide) output per kg of milk produced, as reported by a comprehensive literature review (Rahimi et al., 2022).

Species	DM intake (kg)	Water intake (l)	CO_2 output (kg)
Cattle	1.78	5.73	7.25
Goats	1.43	2.73	6.70

Asia has the largest share of the world's goat population, producing 59.7% of global goats milk (Figure 1-2), and are making investments in large-scale dairy goat projects based on their resilience to climate change (Miller and Lu, 2019). This drive towards higher production from fewer animals is likely to increase intensive husbandry practices globally and put greater pressure on factors such as the amount of space and feed given to animals; for example, in 2021, Europe produced 14.9% more milk than they did in 2011 from 12.9% fewer goats (FAOSTAT, 2023). In his book chapter 'Animal welfare and the intensification of animal production' David Fraser referred to three changes that make up this intensification process – the consolidation of animal production into fewer, larger farms; the concentration of animals into smaller spaces (particularly indoors); and a drive to cut costs resulting in increased confinement, limited human interaction and minimising additional resources (Fraser, 2008). Evidence suggests that goats confined in intensive housing systems experience lower welfare than those in semi-intensive systems (Silva Salas et al., 2021). Overall, the dairy goat sector is becoming increasingly commercialized (Miller and Lu, 2019), and with a push for increasing productivity, a process of intensification seems inevitable and will likely result in greater numbers of kids being reared away from their dams on artificial milk supply systems.

Despite the ubiquitous nature of goats, little is known about production systems globally. Research has focused largely on nutrition, veterinary health, and genetics, as evidenced by the International Goat Association's scientific journal Small Ruminant Research. However concerns have been expressed over the low commercial applicability of this research (Morand-Fehr and Lebbie, 2004). Whilst in the dairy cow industry there has been growing research and industry attention paid towards youngstock management (Costa et al., 2016), the same cannot be said for the dairy goat industry, with the last review of youngstock rearing being published in 1988 (Lu and Potchoiba, 1988). The dairy cow sector has a wealth of scientific literature from the last 100 years to draw on when implementing management practices for youngstock, and within more recent years this has increasingly focused on animal behaviour and welfare (reviewed by Kertz et al., 2017), however this shift has not been evident within the goat research field.

Raising healthy and productive replacement animals is the foundation of future herd health and productivity (for an extensive review of dairy cow evidence see Palczynski et al., 2022), and is therefore integral to the structure and success of a dairy-based business, yet dairy goat farmers have little scientific guidance on best-practice protocols for rearing their youngstock. No validated welfare assessment protocol exists for youngstock, and initial surveys suggest that industry standards are highly variable (Anzuino et al., 2019; Belanger-Naud et al., 2021) with minimal published guidance available. With a rise in consumer concern and growing awareness around the separation of youngstock from their dams (reviewed by Placzek et al., 2021)) there is a need for greater understanding of high-welfare practices within goat youngstock management as this could impact future assurance scheme compliance and marketing abilities. Furthermore, it is well evidenced for all ruminant species that the milk feeding stage and weaning transition are a high-risk period when many physiological challenges take place, and goat kids are no exception, with >90% of goat deaths on commercial dairy farms incurred during these first months of life (Todd et al., 2019).

On the majority of commercial dairy goat farms (farms supplying milk and milk products for consumption by the general public) it has become standard management to separate the kid from the dam (UK 45/46 farms, Anzuino et al., 2019; Canada, 97/103 farms, Bélanger-Naud et al., 2021; USA, 29/30 farms, Hempstead et al., 2021), as rearing kids naturally alongside their dams is considered unviable in terms of both economics and management. These recent dairy goat farmer surveys have reported that it is common to remove the kids soon after birth; 76% immediately in the USA (Hempstead et al., 2021) 65% before first suckling in Canada (Bélanger-Naud et al., 2021) and 21.7% opting to ‘snatch’ the kid as soon as possible in the UK due to concerns over disease transfer such as Paratuberculosis (Anzuino et al., 2019). Once separated from their dams, kids must adapt to being fed milk artificially. It is uncommon for large scale goat producers to follow a restricted milk feeding schedule (Anzuino et al. 2019; Bélanger-Naud et al., 2021; Hempstead et al., 2021) as is the norm for calf rearing (Khan et al., 2011).

Health and environmental needs have previously been the focal points of youngstock literature; whilst these are important contributing factors to animal welfare they focus purely on the biological functioning of an animal, whereas welfare is a multidimensional concept that cannot be explained by one factor alone. In 1997 three factors were proposed as ethical concerns that impact quality of life; the expression of natural behaviours, optimal biological functioning and minimising negative emotional states whilst experiencing ‘normal pleasures’ (Fraser et al., 1997). This multidimensional concept has since been updated, and the most recent conceptualisation of animal welfare includes five domains which explicitly consider both positive and negative experiences within nutrition, environment, health, behaviour, and their impacts on an overarching ‘mental state’ (Mellor et al., 2020). Evidence categorically shows that

whilst physiological wellbeing is an integral part of animal welfare it cannot represent good welfare alone. With a greater emphasis being placed on the ability of farm animals to lead ‘a life worth living’ or ‘a good life’ (Webster, 2016), in order to give recommendations to improve welfare we must research beyond physiological measures and consider additional factors that are likely to reflect an animal’s psychological wellbeing.

Whilst a shift has been seen in this consideration of positive animal welfare within farming systems, one aspect of welfare that has been under considered is that of individuality; that is the differences between individuals and how this impacts their ability to cope with, and have good welfare in, a particular system. This is especially important as the concept of animal welfare has been broadly defined as a measurable quality of living at a specific time for an individual animal (Broom, 2011), yet within farm animal welfare research the individual has been largely overlooked in favour of group and pen level approaches (Fraser, 2009). Recently, views have been changing with reviews published discussing this issue and promoting the wider consideration of individuality within this scientific field (Richter and Hintze, 2019; Winckler, 2019), as if the aim of welfare science is to reduce suffering and promote positive experiences we should be concerned about each individual within a group (Winckler, 2019). This concept of individuality is often linked to the field of ‘personality’ research (behavioural differences between individuals that are both temporally and contextually consistent, (Weiss, 2018), an important new research area particularly as ‘personality’ seems to be closely related to an animal’s ability to cope with different stressors (Finkemeier et al., 2018). The existence of individual coping styles could be particularly important in environments with a high number of stressors or coping-challenges which seems highly relevant during the milk feeding stage and weaning transition. During this period goat kids are expected to cope with a combination of stressors including separation from their dams, introduction to a new social and physical environment, and then the transition from milk to solid feed without experienced social models.

For individuals to have good psychological wellbeing they must be able to fulfil highly motivated patterns of behaviour (Hughes and Duncan, 1988), sometimes referred to as ‘ethological needs’ which they have evolved to perform; for example, calves that are fed milk via a bucket are having their physiological nutritional needs met but experience decreased welfare due to an unfulfilled need to suckle a teat (Fraser et al., 1997). With increasing intensification driven by the push for higher productivity likely, restrictive commercial environments become more prevalent, and within these systems it is often difficult for animals to perform a naturalistic behavioural repertoire (Mason and Burn, 2011; Newberry, 1995) which is likely to include their ethological needs. The inability of individuals to perform natural and highly motivated species-specific behaviours is of high importance not only to welfare scientists (Fraser, 2008), but also to the wider public who hold concerns over the lack of ‘naturalness’ in common commercial

practices such as offspring separation from their dams (Hötzel et al., 2017). However, we lack information regarding the ethological needs of young goat kids due to a dearth of behavioural studies within naturalistic environments, with studies focusing on describing adult social structures (Shackleton and Shank, 1984; Shank, 1972; Shi et al., 2005), sexual behaviours (Dunbar et al., 1990) and adult foraging strategies (Goetsch et al., 2010; Lu, 1988; Shi et al., 2003). Studies focusing on kid behaviour describes their hiding behaviour within the first seven days of life (Lickliter, 1984) and their activity patterns and social preferences until 15 weeks old (Lickliter, 1987). Indeed, this is reflected by a recent literature review aiming to understand natural behaviour of goats to improve dairy goat management systems focused primarily on adults with no discussion of artificial milk rearing systems and weaning of kids (Zobel et al., 2019b).

Whilst there may be little information regarding goat kids' behavioural needs, research on how commercial husbandry conditions impact other species can be extrapolated. Evidence suggests that barren and non-structured environments can cause welfare issues, such as stereotypies and boredom (Meagher, 2019), and that animals reared in captive conditions often experience a reduction in behavioural flexibility as a result (Price, 1999). Thankfully providing species-appropriate enriched environments leads to the opposite; neural and behavioural changes that are likely to promote behavioural flexibility (Clemenson et al., 2015). Enrichment is beneficial to many farm animal species (reviewed by Bolt and George, 2019), and in limited goat kid studies has been evidenced as providing growth benefits (although the gains in both groups were poor, Flint and Murray, 2001), increasing behavioural repertoires (Tölü et al., 2015), and reducing stress (Rosas-Trigueros et al., 2017), yet we currently know little about on-farm usage of environmental enrichment for goat kids. Furthermore, even when species-specific enrichment has been well validated, habituation remains a challenge for its long-term effectiveness (reviewed by Tarou and Bashaw, (2007), and strategies to ensure enrichment is feasible for use on-farm and engaging in the long-term should be an important consideration for future research.

The processes of intensification that result in animal welfare concerns of commercial conditions have been seen in other prevalent farmed animal species (particularly cows, pigs and poultry; for an overview see Fraser, 2008). Whilst in 2001 it was stated that most goats are reared in traditional, extensive systems (Fraser et al., 2001), the shift to a higher milk yield from a smaller number of animals (for example in Europe there has been a 31.9% increase in milk produced per goat; FAOSTAT, 2023) and increases in large housed dairy herds (Miller and Lu, 2019) suggests that this has changed over the last 20 years, and that intensive systems are being increasingly utilised. Intensification of dairy goat farms results in greater numbers of dams and kids being separated, which is known to decrease the ability to perform natural behaviours

and impair overall welfare (Miranda-de la Lama and Mattiello, 2010). Currently the farm animal welfare sector is experiencing a dramatic increase in consumer awareness and public scrutiny (Alonso et al., 2020) concomitant with an increasing demand for higher-welfare assurance schemes, therefore it is essential that farmers have access to clear knowledge on suitable strategies to improve welfare on-farm. This research needs to be species, system, and age specific in order to best optimise animal welfare.

1.2 Aims and scope of the thesis

Whilst the literature available for dairy calves may be considered relevant to goats due to their ruminant physiology, there are marked differences in both their ethology and domesticated conditions which means their responses to management strategies are likely to differ, and it is therefore essential that goat-specific research is performed in order to ensure that appropriate management strategies are implemented to fulfil moving towards the goal of optimising goat kid welfare. Because of the prevalence of practices such as dam-offspring separation, artificial milk feeding and early weaning on commercial farms and the likely animal welfare concerns created by them, alongside the greatest morbidity and mortality occurring during this period, this thesis focuses on goat kids during the milk feeding stage and weaning transition. Whilst the importance of youngstock management is well recognised, it appears that goat kids have not yet been fully integrated into scientific research in the same way that adults have. It is apparent from the information available that goat kids raised on commercial farms, away from their dams, are managed in a manner fundamentally different to their ethological needs, in artificial groups of similarly aged kids fed milk replacer through machines and weaned abruptly and earlier than normal –therefore efforts should be focused onto developing an understanding of their behaviour and welfare during this period.

The prevalence of different dairy goat kid rearing systems, development of optimised youngstock husbandry practices, and understanding species-specific behaviour in goat kids have garnered limited research attention. Therefore, the research developed in this thesis intends to achieve the overall aim described in Figure 1-3 and will be fulfilled by the outlined contents. This thesis begins with a literature review (Chapter 2) that explores the current state of knowledge and provides justification for the research aims. Five research chapters follow, as visualised in Figure 1-3; Chapter 3 used a farmer survey to understand how farmers are currently rearing goat kids away from their dams, data which was further utilised within Chapter 4 to understand farmers views on changing their current management. Chapter 5 establishes an important baseline by quantifying the feeding behaviour of goat kids reared on ad libitum milk feeding systems, and in Chapter 6 gradual methods of weaning from these systems (that would be feasible for on-farm use) are investigated. In Chapter 7, ways to understand the consistency

and validity of measuring the individuality of goat kids are investigated using novel object and familiar person tests. Finally, these pieces of research are discussed as a whole in Chapter 8, and wider implications of this body of work for both the goat industry, and for science, are postulated.

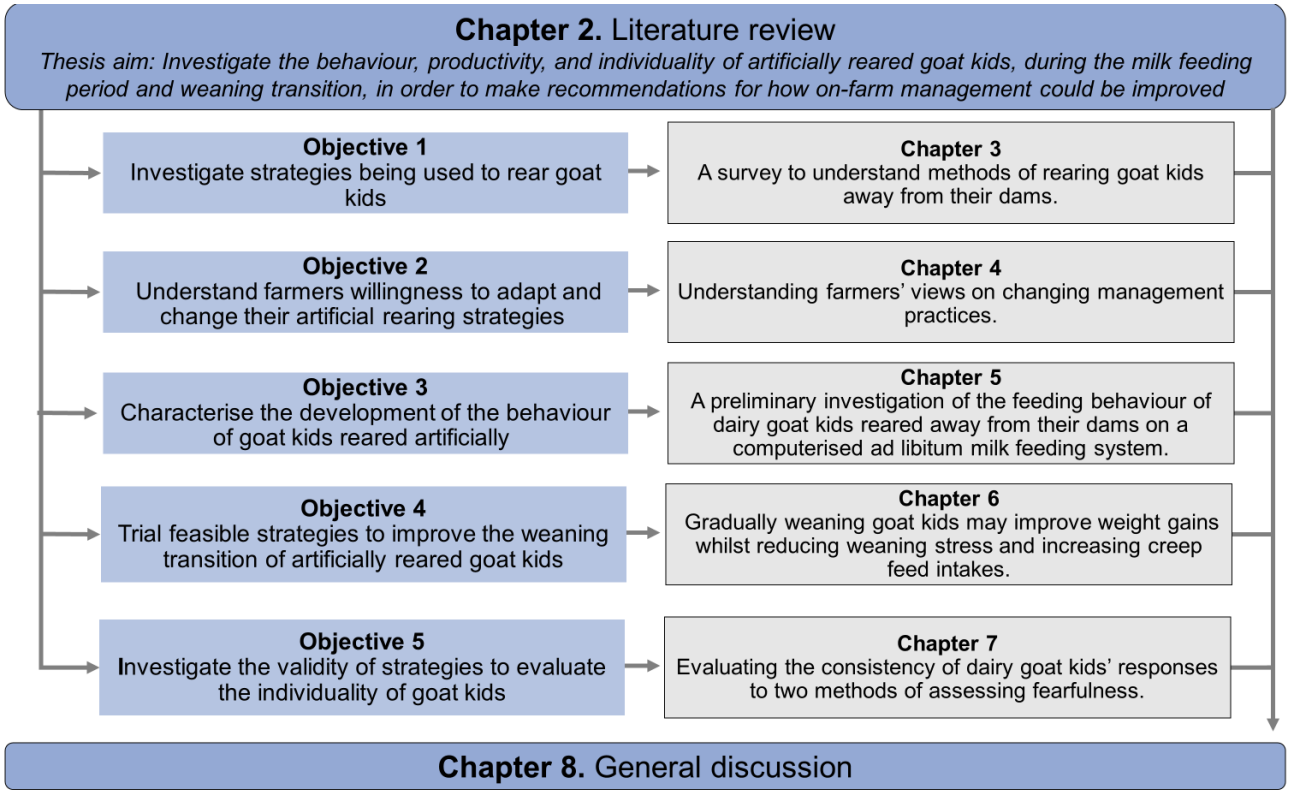

Figure 1-3. An overview of the structure of this thesis – demonstrating the research objectives and their corresponding chapters.

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2. A literature review

2.1 Early life management of artificially reared goat kids

2.1.1 Kid separation from dam

The removal of goat kids from their dams is a widespread practice for a multitude of reasons, which appear to be primarily driven by economics and the production of milk for human consumption. The length of time the kids spend with the does before being artificially reared is variable, with the decision to remove immediately after birth a widespread practice that differs in prevalence across countries (21.7% UK, Anzuino et al., 2010; 65% Canada, Bélanger-Naud et al., 2021; 76% USA, Hempstead et al., 2021). The early removal of kids is due to the strategy of natural maternal rearing being considered unviable for a wide array of reasons, (whilst this has not been explored for dairy goats, a comprehensive review for dairy cows was performed by Johnsen et al., 2016). It also appears to be related to concerns over the transfer of infectious diseases (Anzuino et al., 2019) – particularly Johne's disease (Mycobacterium avium subspecies paratuberculosis) which can be transferred via the placenta and milk of infected does (Manning et al., 2003) but is most commonly shed via faeces (Windsor, 2015). Whilst the implications of prolonged doe-kid contact need further investigation, this area is not a focus of this thesis; colostrum and early kid management from a veterinary perspective is currently being investigated by Katherine Anzuino of the University of Bristol.

Under typical management most producers separate the kids from their dams at an early age (Anzuino et al. 2019, Bélanger-Naud et al., 2021, Hempstead et al. 2021) therefore most dairy goat farms have not been designed to accommodate the kids staying with their dams, this necessitates a need for research that aims to understand how goat kids use, and respond to, artificial rearing systems. This is particularly relevant with the current increasing emphasis on future productivity, with most UK farmers aiming to have kids mature enough to have their first oestrus and subsequent mating at 6-7 months of age, then produce their first litter and enter the milking herd at 1 year (Anzuino et al., 2019); a goal which is contingent on good preweaning growth rates and health. As yet there are no clear benchmarking figures for dairy goat kid growth, with just one short communication reporting multi-farm (n=16) growth rates averaging 180±40 g/day up until weaning and 137±66 g/day until two weeks post weaning (Deeming et al., 2016); however, they noted that one farm consistently achieved >200g/day which suggests higher rates are achievable with differing management. Minimising stress and growth checks (Gökdal et al., 2017) during the milk feeding stage and weaning transition is essential to ensure future growth and therefore reaching productivity goals, particularly as there are multiple incidences of stressful events during this short period of time (Figure 2-1).

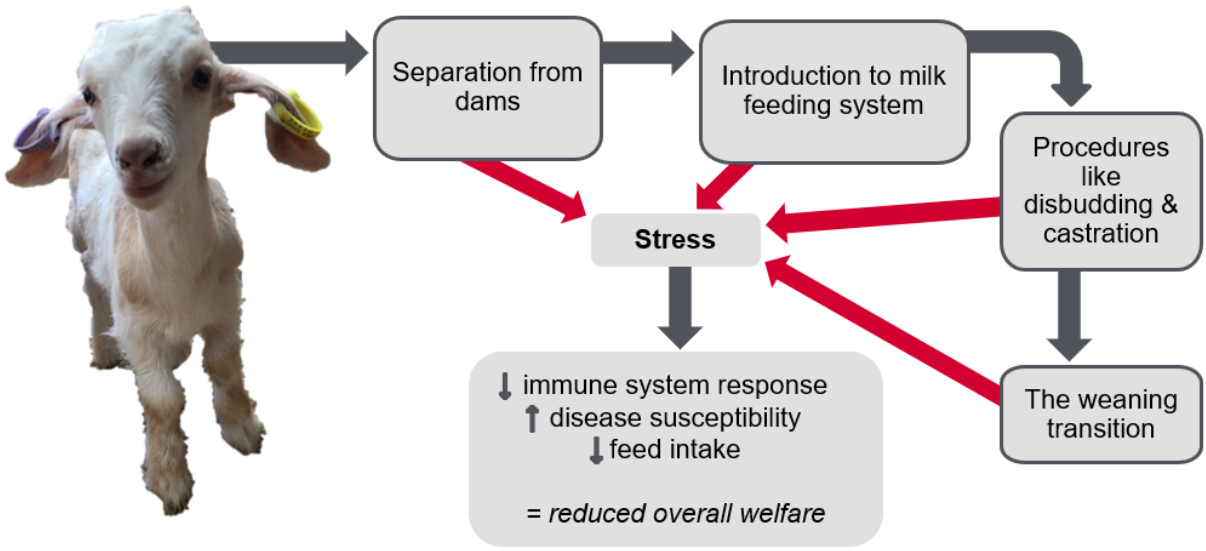


Figure 2-1. The impacts of typical early life management of artificially reared goat kids.

2.1.2 Artificial rearing systems

From the basic survey information collected on youngstock management it appears that once kids are removed from their dams, the majority of commercial goat milk producers introduce kids to ad libitum milk feeding set ups that allow constant, unrestricted access to milk (Anzuino et al., 2019). From the larger body of research that exists for dairy calves, individuals are generally fed milk on a restricted meal-based schedule, which became popular due to early research suggesting that limited milk intakes resulted in increased consumption of solid feedstuff and therefore facilitated early weaning (reviewed by Savage and McCay, (1942)). However, within recent decades there has been a greater focus on the implications behind following this protocol. Multiple studies have shown that compared to naturally reared calves, restricted milk feeding results in reduced weight gain (Flower and Weary, 2001; Hammon et al., 2002; von Keyserlingk et al., 2009), and it has been further suggested that this method of feeding reduces calf welfare, due to the prevalence of abnormal behaviours (De Paula Vieira et al., 2008; Rushen and de Passillé, 1995; von Keyserlingk et al., 2009). With a growing knowledge of the disadvantages associated with restricted milk feeding, research has been conducted to understand the impacts of increasing milk supply to calves in the dairy industry. Whilst benefits including higher weight gains and increased natural behavioural expression (Appleby et al., 2001; Diaz et al., 2001; Jasper and Weary, 2002), disadvantages were also identified; including reduced solid feed intake (Jasper and Weary, 2002), resulting in slower development of the rumen (Khan et al., 2007).

Extrapolating from the research conducted in dairy calves it would suggest that whilst the goat kids fed on ad libitum systems may well have increased weight gain and express a more natural behavioural ethogram compared to those limit-fed, lower solid feed intake and slower rumen development may be an issue, particularly during the weaning transition when kids are expected to cope with the sudden loss of milk intake by increasing their solid feed intake dramatically. Deciding to wean based on body weight is a common strategy within the United Kingdom (Anzuino et al., 2019),Canada (Bélanger-Naud et al., 2021), and New Zealand (Todd et al., 2019). In a study considering weaning weights of goat kids, 32 kids were distributed into groups that weaned at 8,9,10 and 11 kilograms of body weight. Whilst mortality issues (attributed to coccidia infections combined with weaning shock) reduced the sample size it was concluded that compared to weaning by age, weaning shock was less severe in kids weaned based on weight (reviewed by Lu and Potchoiba, 1988)). Indeed, it has been suggested that weaning shock is more closely related to weight rather than kid age (reviewed by Lu and Potchoiba, (1988)), however, it seems difficult to separate the two, and the evidence surrounding this is based on old data and limited sample sizes.

2.1.3 Considerations for improving management

There are multiple challenges around improving such a transition, not least of which centre around creating methods that are feasible for use on-farm and are acceptable to farmers themselves. Farmers, as those responsible for the daily management of animals under their care, have a huge influence over their welfare (Boivin et al., 2003; Hemsworth, 2003; Rushen et al., 1999; Waiblinger et al., 2002). Changing animal management within these systems relies on best-practice research being adopted for on-farm use, and we know that whilst farmers may perceive animal welfare as important, they often find changes proposed to improve it difficult to implement within real world scenarios (Kauppinen et al., 2010). It has been highlighted by goat scientists that basic research related to goat farming, such as understanding systems of production and ‘proposing methods and know-how acceptable to farmers’, should be a research priority (Morand-Fehr et al., 2004). To have the largest impact, it is essential that research is targeted and feasible for application on farm, and as farmers implement husbandry and management practices daily, understanding their views regarding changing their current management practices will help to ensure this, particularly around the important transitional phase of weaning.

‘Participatory’ research approaches are strategies that have been proposed to address this need and focus on the active participation of the end-user in an early stage of planning research, in order to better tailor academic research to the needs of the end user (Cornwall and Jewkes, 1995). It has been demonstrated that farmer attitudes are integral to the adoption of

new practices, and that the transfer of knowledge for farming systems needs to consider the opinions of these potential adopters (Rehman et al., 2007). Using this information within a participatory research approach could address the needs of farmers and should then be followed up with on-farm or animal-based research projects (Vatta et al., 2011) to ensure thorough investigation of proposals. However, one of the challenges when proposing new livestock management techniques is that is has been reported that many farmers consistently believe that their livestock have no welfare issues (Te Velde et al., 2002), or underestimate welfare issues (reviewed by Balzani and Hanlon, 2020), and research shows that if farmers cannot be convinced that there is a problem, and that their actions could improve it, then changes are unlikely to occur (Blackstock et al., 2010). A Department for Environment, Food and Rural Affairs (DEFRA) commissioned review (UK) recommended that farmers should be involved in the planning stage of research to ensure that resulting findings are feasible and have the greatest possible potential of adoption (Rose et al., 2018). This evidence illustrates the need for research to demonstrate potential for improvements, create evidence of a wide range of benefits associated with these improvements, and propose changes that are feasible for use.

The management practices used by farmers during the early-life rearing stage is particularly important to the welfare and future development of an animal. There is an increasing body of evidence that early life growth rates have large influences over lifetime productivity of dairy cows, with higher early growth resulting in increased milk yields (Moallem et al., 2010; Soberon et al., 2012), increased body weights at 24 months of age (Moallem et al., 2010) and reduced age at first calving (Raeth-Knight et al., 2009). The milk feeding stage seems particularly important to this later life productivity, with pre-weaning growth rates accounting for 22% of the variation in a dairy cows first lactation yield (Soberon et al., 2012), which is higher than the influence of genetics. It is not just productivity that is impacted by early life experiences; evidence shows that there are behavioural differences in animals that are reared in simple and unvarying (non-cognitively demanding) early environments (Price, 1999) which impacts their ability to cope with environmental changes. As many goat-kid rearing environments are barren and constant for reasons of hygiene and practicality, providing species appropriate enrichment seems a particularly important consideration.

2.1.4 Environmental enrichment

The adding of provisions intended to enhance the performance of, or increase the complexity of, an animal's natural behavioural repertoire is well known to increase captive animals' behavioural repertoires and improve their overall welfare (Newberry, 1995), and many farming industries use enrichment in commercial systems to this affect (for an overview see Bolt and George, 2019). Overall, it is accepted by behaviour and welfare scientists that commercial

systems restrict natural behavioural repertoires and therefore strategies that allow greater natural behavioural expression are positive, particularly in early life (Clemenson et al., 2015). Increasing the complexity of the environment an animal is reared in can promote behavioural flexibility (Clemenson et al., 2015), which can help individuals better cope with management-related stressors (Zobel and Nawroth, 2020). This seems particularly relevant for kids during the milk-feeding stage and weaning transition when they are expected to cope with large changes to their feeding regimes, often in addition to changes to their social and physical environment.

For environmental enrichment provisions to be efficacious it is essential that they are biologically appropriate and consider the natural ethology of a species (Newberry, 1995). Wild goats generally inhabit complex topography often consisting of steep mountainous terrain at high elevations (Parrini et al., 2003). Goats utilise this topography extensively, using steep cliffs as an escape route to avoid predation (Sarhangzadeh et al., 2013), elevated areas as vantage points (Iribarren and Kotler, 2012), and caves for resting (Boyd, 1981; Shi et al., 2005, 2003), for shelter from inclement weather (Boyd, 1981), and as protection from human predation (Kessler et al., 2003). Domestic goats in extensive dairy systems also use caves for shelter (Zobel et al., 2019b), showing how these habitat preferences appear to have been conserved through the domestication process. These innate behaviours demonstrate that enabling goat kids to exhibit a complex behavioural repertoire including climbing, hiding, and browsing opportunities within captive conditions could be beneficial to their overall welfare.

It seems that the complexity of their environment serves a multitude of purposes and therefore the opportunities for goats to perform their full behavioural repertoire may be restricted by the typical commercial farm set up, which generally allows little variation in elevation, surface type and hiding opportunities. In zoological collections providing species with environments that are complex and representative of their ecological niche is recognised as important (Newberry, 1995), but this consideration is generally not made within commercial farms, with practicality and hygiene reasons often resulting in uniform, undemanding environments. Zobel et al., (2019b) suggested that whilst providing additional shelter within an indoor system may seem superfluous it could allow for individuals to perform a more natural behavioural repertoire, and a recent review of providing hider spaces to farmed animals concluded that they have a generally positive impact on welfare (although only one goat study was included: Spitzer et al., 2022). This may be particularly relevant for goat kids which are considered ‘hiders’ and will actively seek out opportunities for shelter(Lickliter, 1987), a behaviour which continues up until six weeks of age in the wild (Mcdougall, 1975).

It has been evidenced that providing adult domestic goats with the opportunity to climb and feed in elevated structures increased feeding bout duration, decreased agonistic behaviour and decreased disruption from lying (Aschwanden et al., 2009). The provision of items that

allow goats to express natural behaviour can have far-reaching benefits. In one study limited by a lack of pen replication the effects of enrichment were investigated, 2 groups of 20 goat kids were removed from their dams from 9am-6pm daily and placed into ‘structured’ (pens with additional structures such as a bridge and woodblock) or ‘unstructured’ (no items and paddock sides enclosed to prevent bipedal stance)’ environments. The authors concluded that unstructured environments limited the behavioural repertoire of goat kids, and that younger kids have a higher demand for an enriched environment. Overall, they suggested that the behavioural needs of goat kids are not met in an ‘unstructured’ environment (Tölü et al., 2015), which may be a common characteristic of goat kid rearing facilities.

However, even when enrichment has been scientifically validated, habituation remains a serious challenge around its long-term effectiveness (reviewed by Tarou and Bashaw, 2007)), particularly for simple inanimate objects, which are often the most feasible addition for farmers. It may be that communication to farmers around rotation of enrichment items could combat this, as has been evidenced in other species (Renner et al., 2000). Habituation may also be impacted by animal age, and whilst age difference effects have been scarcely studied in farm animals, they have been clearly observed in pandas (Swaisgood et al., 2001) and chimpanzees (Lambeth and Bloomsmith, 1992). It has been theorised that there is a greater intrinsic reinforcement for play in juvenile individuals (Fagen, 1981) which may explain differences in enrichment effectiveness between age groups, with young animals habituating at a slower rate. This is an important consideration for future research and tailoring enrichment requirements to goat kids versus adults.

With little peer reviewed research investigating enrichment provision for goat kids during the milk-feeding period there is limited evidence with which to persuade caregivers of the benefits enrichment can provide. As enrichment is a beneficial addition to the environment of many other farm animal species (reviewed by Bolt and George, 2019), and in limited goat kid studies enrichment has been evidenced as providing growth rate benefits (Flint and Murray, 2001), increasing behavioural repertoires (Tolu et al., 2017), and reducing stress (Rosas-Trigueros et al. (2017), there is a need for further research to identify suitable enrichment items for goat kids that are feasible for farmers to use. Research aiming to investigate specific enrichment for goat kids in order to recommend safe and efficacious species-specific enrichment that improves overall welfare would be warranted. However even in species where extensive research evidencing demonstrable benefits has been conducted, poor industry implementation remains (discussed for pigs; van de Weerd and Ison, (2019) so the need for improved communication with farmers remains an essential consideration.

2.2 Development of feeding related behaviours

2.2.1 Milk feeding behaviour

Typically, under commercial management when kids are separated from their dams, they are fed milk through artificial teats that are attached via tubes to a machine (Anzuino et al., 2019; Bélanger-Naud et al., 2021). These simplistic ad libitum feeding systems simply mix milk powder and water which flows to the teat when the kids suckle, and do not use technology to monitor individual milk intake as is common in calf rearing (Rutten et al., 2013). The average milk consumption for a dairy goat kid allowed ad libitum milk access has been estimated at 25% of body weight up to 4 weeks old, and 15% thereafter (Lu and Potchoiba, 1988) however, it is unclear where this estimation comes from and its accuracy is questionable. There is currently no literature that has utilised technology to accurately quantify the amount of milk individual goat kids consume on ad libitum milk systems – information that is essential to further understanding the milk-feeding stage and weaning transition.

Large inter-individual variations in milk consumption and its impacts on weight gain have been reported in other ruminant species; during the first four weeks of life dairy calves' range in intake from 2.4 to 12 litres of milk per day resulting in average daily gain ranges from 0.07 to 1.2kg (Rushen, 2016), and artificially reared lambs milk intakes varied from 0.3 to 2.9 litres per day (David et al., 2014). The extent of inter-individual milk intake variation in goat kids is currently unknown, and there is also no information regarding how often they feed from ad libitum milk systems, this is important as it could impact solid feeding behaviour. In artificially reared lambs an average of 9.5 milk meals per day has been reported (David et al., 2014), this varies considerably from animals that are reared naturally with their mothers, as it has been reported that lambs consume 22 milk meals in 16 hours (Munro, 1956). There is further information from lambs (David et al., 2014) and calves (Borderas et al., 2009) that milk meals in artificial systems are distributed evenly throughout the entire day, which could have management implications including milk availability and gradual weaning timings, but again this information has simply not been evaluated for goat kids.

The development of feeding behaviour has been explored in much greater detail for calves, and this literature forms the basis for assumptions currently made about goat kids. This body of evidence has resulted in restricted milk feeding methods becoming commonplace within dairy calf rearing, in an effort to improve pre-weaning solid feed intakes (Terré et al., 2007; Weary et al., 2008) in order to enable early weaning and the economic viability of artificial calf rearing. Whilst no research that specifically investigates the feeding behaviour of goat kids reared on artificial milk supply systems has been published, there are studies investigating the provision of milk to lambs (David et al., 2014) and calves (Brscic et al., 2009; von Keyserlingk et

al., 2004). One study investigated the health of calves reared on automatic milk feeding systems and noted that the percentage of calves with poor body condition increased over time, this was suggested to be due to the ratio of teats to calves causing increased feeding competition and reduced milk intake by lower ranking individuals (Brscic et al., 2009). This supports earlier findings that reduced access to milk teats, caused by a higher calf to teat ratio, showed increased competitive interactions, resulting in decreased feeding time and milk intake (von Keyserlingk et al., 2004). From research conducted on other species, it is known that feeding competition has quantifiable impacts on growth, health and behaviour. Increased feeding competition in pigs results in larger variability in weight gains, with the smaller animals showing the lowest growth rates (Georgsson and Svendsen, 2002), and increases the incidence of skin lesions (Botermans et al., 2000). However, these studies relate to the provision of hard feed, and there are few studies related to the feeding of ad libitum milk via teats.

Possible issues regarding feeding competition are compounded by the phenomenon known as behavioural synchrony, which refers to groups of animals participating in activities collectively. Feeding synchrony has been investigated in some of the production species such as sheep (Ramseyer et al., 2009), and poultry (Appleby et al., 2004). The effects of this kind of synchrony may be particularly important in artificial milk feeding systems as a small number of teats are shared by a larger number of animals, therefore, it seems likely that competitive interactions could be problematic and impact feed intakes as well as welfare more broadly. Indeed, in one of the few studies to investigate the use of ad libitum milk feeding machines, it was found that on average 65% of lambs in the pen wanted to feed at the same time, and for 35% of meals the relative group meal size was >90% of all lambs in the pen (David et al., 2014). However, these lambs had no access to solid feed and therefore motivation to access milk was likely higher than in typical commercial rearing conditions where solid feedstuff is available. Whilst we know that the majority of commercial dairy goat kids are reared on ad libitum milk supply systems (Anzuino et al., 2019), it is important to understand the impacts that feeding competition can have on milk intake in these systems, as unlike dairy calves, the technology is currently not in place to monitor and ration milk intake on an individual level.

From calf studies utilising this individual technology it has been highlighted that providing more milk teats reduces feeding competition (von Keyserlingk et al., 2004), with higher ratios of animals to shared teats resulting in increased levels of feeding disturbances (Jensen, 2003) which could impact intakes. Within milk feeding systems, physical barriers can be used to reduce competition and resulting displacement (Jensen et al., 2008) and are commonplace for calves as individual recognition relies on only one animal accessing the milk feeder at a time. However, within goat kid systems the teats are generally placed on an open side with no protection (personal observation). It is currently unknown how feeding competition impacts goat

kid feeding behaviour, and what ratios of individuals to shared milk teats are commonplace on farms, however widely published and distributed industry guidelines for lambs of 15 animals per milk teat (Lamlac, 2019) are commonly transferred to goat kids (Volac, personal communication).

2.2.2 Solid feeding behaviour

Whilst initially goat kids rely entirely on milk, they begin to consume small amounts of solid feed within the first few weeks of life (Nicol and Sharafeldin, 1975), and this continued, increasing intake of solid feed is essential to the rumen development that enables successful weaning (reviewed for calves by Khan et al., 2016)). It has been well evidenced that young ruminants that have not adequately increased their solid feed intakes at the time of milk removal (weaning) experience more severe growth checks than those who are consuming higher amounts (Khan et al., 2007; Sweeney et al., 2010). Solid feed intakes are closely positively correlated with rumen weight (goat kids: Hamada et al., 1976)), and in calves high milk intakes, such as those provided by ad libitum milk feeders, result in slower rumen development due to reduced solid feed intakes (Sweeney et al., 2010). Calf research suggests that whilst individuals that have been fed milk ad libitum show improved growth rates and increased behavioural repertoires (Appleby et al., 2001; Diaz et al., 2001; Jasper and Weary, 2002), they also have lower solid feed intakes and slower rumen development that becomes problematic during the weaning transition (Jasper and Weary, 2002; Khan et al., 2007).

There are multiple factors beyond the intake of milk that affect solid feeding behaviour; research shows that feed intakes are affected by individual behaviour (Grant and Albright, 2001; Keyserlingk and Weary, 2010; Neave et al., 2018ab), that develops early in life (Provenza and Balph, 1987), and is likely influenced by an array of factors such as the rearing environment, exposure to feeds and physiological differences (Miller-Cushon and DeVries, 2015; Provenza and Balph, 1987). Young animals learn to ingest solid feed through the social development of behaviour, with their dams and other conspecifics within the social group acting as models (Launchbaugh and Howery, 2005). This learning process leads to individualised preferences, and differences in foraging efficiency (Provenza and Balph, 1987). However, without dams or older conspecifics, kids that are reared artificially must learn to access all types of food alone. Social learning has been shown to increase speed of learning to feed from milk teats (Veissier and Stefanova, 1993) and has been further demonstrated to play a significant role in the development of foraging behaviour in young ruminants (Launchbaugh and Howery, 2005). Naïve calves show increased grazing levels when at pasture with an older, experienced companion rather than without (Costa et al., 2016; Hessle, 2009).

Theories of social learning have suggested that the most efficacious models from which to learn are the dam and other dominant peers (Bandura, 1977; Laland et al., 1996), and in cattle the natural composition of large mixed-generation groups (Reinhardt and Reinhardt, 1981) enables the transmission of suitable feeding behaviours via social learning to inexperienced group members (Boyd and Richerson, 1988). Dam contact within the pre-weaning phase enables young animals to begin consuming solid feeds at earlier ages, and in larger amounts; calves reared with their dams begin grazing on pasture from two weeks of age (Nicol and Sharafeldin, 1975). Food neophobia (the avoidance of, and reluctance to consume novel feedstuff) has been commonly observed in ruminants (Chapple and Lynch, 1986) and is a strategy to avoid trial and error learning that could lead to the ingestion of toxic substances. Social learning enables young animals to avoid this type of 'trial and error' when learning how to select appropriate foodstuff and decreases food neophobia and increases intakes of suitable substances (lambs: Beck et al., (2021), Nolte et al., (1990); calves: Costa et al., (2014); De Paula Vieira et al., (2010)). All ruminants are likely to learn feed preferences through allelomimicry using conspecifics (dams and peers) as models (Mirza and Provenza, 1990). Whilst goat kids are not reared in isolation as is often commonplace for dairy calves, they are typically housed in groups of naïve kids close in age, without dams and older experienced individuals; this lack of social models is likely to play a role in how, and when, they begin to feed on solid feeds, and warrants further investigation.

It is well known that development of the reticulo-rumen is affected by the physical form of the diet (Nocek et al., 1980), and therefore the type of feed consumed during early life is important. If neonatal ruminants are fed solely milk during the early months of their life, they experience limited rumen development with respect to rumen mass (Smith, 1959; Tamate et al., 1962) and papillary growth (Tamate et al., 1962; Warner et al., 1956), when compared to those with access to grain and hay. Even when ruminants are offered ad libitum milk access, they begin to consume solid feeds from two weeks of age and appear to covet it even when it is not available (Forbes, 1971). Indeed, if solid feed is unavailable, calves consume bedding material, suggesting ruminants possess an innate hunger for solids (Diaz et al., 2001).

There is mixed evidence in the literature regarding how forage and concentrate feeds impact growth and feeding development of young ruminants, with research typically focussing on these effects in calves. It is generally well evidenced that the provision of forage such as hay to calves before weaning has beneficial effects, such as by increasing dry matter intake and improving rumen development (Khan et al., 2011), increasing rumen mass (Castells et al., 2013), and promoting better muscular development (Beiranvand et al., 2014). Furthermore, forage provision plays a role in maintaining beneficially lower pH levels (Khan et al., 2011; Castells et al., 2013) and therefore reducing the incidence of rumen acidosis (Castells et al.,

2013), which is particularly important during the dietary changes of weaning when forage intake mitigates ruminal acidosis risk and increases bacterial diversity which aids digestion (Kim et al., 2016). However, some studies have documented no forage related effects on growth (Khan et al., 2011), or on growth, feed intake and digestion (Wu et al., 2017).

One study has investigated the provision of differing feed types to 44 goat kids before weaning, in this research all kids were individually housed (which has negative welfare implications) and fed two milk meals per day at the rate of 1 litre/meal from 0-20 days then 0.5 litres/meal from 20-40 days when they were weaned (Jiao et al., 2015). The kids were then split between a grazing group that went to pasture for 8 hours a day and returned to individual pens overnight, and a group that received cut forage from the same grazing alongside a concentrate feed (however feed intakes were not recorded for either group: Jiao et al., 2015) and four kids from each group were slaughtered at 28, 42, 56 and 70 days of age. The groups did not differ in rumen weight, wall thickness or papilla number, however the authors concluded that their study was the first to demonstrate that supplemental concentrate feeding promoted better rumen development in goat kids due to greater volatile fatty acid concentration, liquid-associated bacterial and archaeal copy numbers, and lower rumen pH (Jiao et al., 2015), suggesting that it is likely important to provide concentrates alongside forage. In one study on just 12 male goat kids from a regional Chinese breed that were weaned from their dams at 45 days of age it was found that miRNAs related to cell proliferation and muscle development were downregulated after weaning, likely due to a stress related response (Liao et al., 2019). These down regulated genes were primarily enriched in salivary and bile secretion which directly relate to digestive system health and function (Liao et al., 2019), therefore efforts to ensure well developed digestive systems before weaning, and to minimise the stress of weaning itself are important to minimise these impacts. However, this study had a small sample size, and the kids were separated from their dams abruptly and at a younger age than most commercial weaning occurs (see section 2.3.1 for discussion of weaning age). There is a lack of published research investigating the effects of both forage and concentrate provision on feed intakes and rumen development on goat kids specifically, likely due to a lack of suitable technology (such as individual feed intake and rumen monitors) validated for use.

In published recommendations for the management of artificially reared goat kids, Hart and Delaney (2016) state that at weaning a kid must have pelleted starter feed intakes of >250g day, but there are no recommendations related to forage intakes. This intake figure is also a widely followed industry guideline for lambs which is commonly transferred to goat kids (Lamlac, 2019), however we simply do not know if this guideline is reached within different rearing systems. Previous research comparing goats and lambs found that lambs are faster than goats to consume solid feed and have increased rumen development as a result

(Economides, 1985), therefore industry guidelines for lambs are unlikely directly applicable to goat kids. In adult goats a high concentrate diet decreased ruminal pH and caused changes in rumen bacteria which was associated with alterations in toll-like receptors that are expressed in the ruminal epithelium (Liu et al., 2015). These receptors are involved in complex immune responses and dysregulation can cause inflammatory and epithelial barrier dysfunction which impacts rumen efficiency (Liu et al., 2013), therefore caution should be taken regarding this industry focus on concentrate feeds as being critical to weaning success when forage intakes are likely also critical and aid with achieving optimal rumen pH levels.

To date, there has been no work conducted that investigates the feeding preferences of artificially reared goat kids, and commercial concentrate feeds designed for goat kids are typically of the same size and shape as has been designed for lambs. It has been found that improving the presentation and palatability of concentrate feed can impact its consumption by dairy calves (Weary et al., 2008), but strategies to increase concentrate feed consumption are yet to be investigated for kids. Naturally, goats are both browsers and grazers (Goetsch et al., 2010) that prefer to feed at ‘eye-level’; browsing at a height approximately equal to, or above that of their own heads (Lu, 1988). This natural feeding ethology is starkly removed from current commercial feeding practices which favour feeding uniform rations at ground level (Zobel et al., 2019). Simple on-farm changes could allow for the increased expression of natural feeding behaviours and may also be useful in understanding feed intake in pre-weaning kids. Raised feeding surfaces have already been successfully utilised for adult goats on commercial farms by raising the middle drive alley between pens (Zobel et al., 2019) but are yet to be tested with kids.

2.3 The weaning transition

Weaning (the process of transitioning a young animal from milk to solid feed intake) represents an important transitional phase of management, that all mammals under human or natural care must undergo at some point in their life. Under natural conditions this transition would take place over an extended period, with multiple cues that cause the young animals to decrease their milk intake concomitant to an increase in solid feed intakes. When goat kids are reared naturally alongside their dams, the kids undergo the weaning transition between approximately 84 and 168 days of age (Collias, 1956). This transition appears to start as early as 35 days of age, when the kids become increasingly independent, spending greater periods of time away from their dams alongside reducing the frequency of suckling events (Bungo et al., 1998). In calves the weaning transition has been particularly well studied. Under naturalistic conditions it occurs over several weeks and is estimated to take place between six and fourteen months of age (Reinhardt and Reinhardt, 1981). This transition involves a dam led process in

which milk availability is reduced via an increase in suckling bouts being terminated by the dam resulting in increased calf forage intakes (Reinhardt and Reinhardt, 1981). It is also clear that during this transition the calf increases social interactions with its peers, due to the decreased dependence on maternal nutrition (Bouissou et al., 2001).

2.3.1 Age at weaning

Under commercial farming management there is a drive to wean animals from milk younger, due to the costs associated with this milk feeding stage, particularly in artificial rearing systems (Delgado-Pertíñez et al., 2009). The expense of milk replacement powder is key to the economic profitability of artificial rearing systems (Delgado-Pertíñez et al., 2009) and has been dramatically increasing (in January 2022 it was reported by the farming press that milk replacer costs had increased 40-50% since summer 2021 – Farmers weekly, 2022), and this economic pressure places a strain on the optimum weaning period - with a trade-off between feeding sufficient milk to obtain optimum growth rates but weaning early enough to remain a profitable enterprise. Earlier weaning could be key to reducing production costs associated with artificial rearing (Khan et al., 2016; Owen and Larson, 1982) and in commercial dairy farms in the UK and USA most goat kids are weaned from artificial milk feeding system between 42 and 56 days of age (Anzuino et al., 2019; Hempstead et al., 2021). However, this varies by region and in New Zealand the median weaning age on commercial dairy farms is 86 days (Todd et al., 2019). This early and artificial weaning transition takes place over a reduced timespan with no dam-led cues such as termination of suckling bouts that result in increased solid feed intakes and is therefore a stressful experience that has been shown to cause growth checks (Lu and Potchoiba, 1988; Newberry and Swanson, 2008) and result in the development of oral stereotypies (Atasoglu et al., 2008).

2.3.2 Methods of weaning from artificial systems

The process of weaning from artificial milk feeding systems can be conducted in a number of different ways and calf studies indicate that the physical method of weaning can influence growth rates (Roth et al., 2009; Weary et al., 2008, 2007). There are two broad styles of weaning young animals from their milk source:

1) Abrupt weaning is the sudden and complete removal of milk from the diet in a single step.
2) Gradual weaning involves some degree of incremental reduction of milk intake before complete removal. This can include reducing the number of feeds per day, quantity of milk per day, or even the dilution of milk.

Most research on the weaning transition of dairy goat kids is outdated and has focused on age of weaning (Morand-Fehr et al., 1991) or weaning and separation from the dams (Sporkmann et al., 2012; Ugur et al., 2007), rather than the physical method of weaning and its impacts on kid behaviour, productivity, and welfare. Two recent studies have been conducted on goat kids that focused on weaning from an artificial milk supply system. One focused on physiological parameters of 11 kids that were gradually weaned by 48 days of age, they found that all physiological parameters remained within normal ranges, however they did not include an abrupt weaning control group so the conclusions are limited. A more detailed study was conducted by Zobel et al., (2019a) using a six-day gradual weaning period that concluded with full weaning at 84 days of age. There were no significant weight gain differences between abruptly and gradually weaned (by either a reduction in milk concentration or volume) kids (Zobel et al., 2019a), however as most kids reared in the UK, USA and Canada are weaned two weeks younger (Anzuino et al., 2019; Hempstead et al., 2021; Bélanger-Naud et al. 2021) these results may not be directly applicable to many artificially reared goat kids, but do demonstrate the important of age.

Gradual weaning has been better studied within dairy calves, and research provides evidence that gradual weaning has benefits over abrupt weaning, including earlier solid feed intake (Scoley et al., 2019), higher growth rates (Weary et al., 2008), and increased gastrointestinal tract adaptation (Steele et al., 2017). This body of research further suggests that the detrimental effects of abrupt weaning are particularly apparent when pre-weaning high milk intakes (such as those provided by ad libitum feeders) are fed, due to decreased solid feed intakes (Terré et al., 2007; Weary et al., 2008); making the practice of feeding milk ad libitum somewhat less attractive in its benefits. Reduced weight gain (or in some cases even weight loss) post weaning has been linked to the slower rumen development of calves fed higher milk quantities (Khan et al., 2007; Sweeney et al., 2010). Overall calf studies suggest that abrupt weaning in both restricted and ad libitum milk feeding systems results in lower growth rates in the period following weaning than gradual weaning (Roth et al., 2009; Weary et al., 2008, 2007), and a review of the literature suggests that calves fed high milk intakes should be gradually weaned to promote sufficient gut development (Costa et al., 2019).

In goat kids, the intake of solid feed has been positively correlated with the weight of the reticulo-rumen (Hamada et al., 1976), highlighting the importance of solid feed intake to rumen development, and subsequently successful weaning. Whilst it has been found that kids consume more solid feed if milk is restricted (Economides, 1986), with most commercial producers using ad libitum milk feeding systems (Anzuino et al. 2019; Bélanger-Naud et al. 2021; Hempstead et al., 2021), this information is not directly applicable to most commercial systems. It is recommended widely that goat kids need to be eating 250 grams of concentrate

feed a day before being weaned to ensure a smooth transition to a solid feed-based diet (Hart and Delaney, 2016). In the only study to measure (pen-level) feed intakes of artificially reared goat kids Zobel et al., (2020) found that they only began to eat significant amounts of 100 grams of concentrate per day once gradual weaning had begun, however the kids did also have access to forage which could not be measured. Therefore, quantifying how milk intakes and weaning methods impact solid feed consumption is imperative to understanding how to improve the weaning transition.

Greater literature exists on the feed intakes of dairy calves, with the technology to monitor individual concentrate feed intakes commonly used in research. These studies have identified large individual variability in calf intakes when on the same weaning treatments, Heinrichs and Heinrichs, (2011) found a 27% coefficient of variance in the age at which 795 dairy heifer calves consumed 0.9kg of concentrate feed. Even when calves are fed restricted milk allowances, they took between 45 and 98 days to hit a target of 2kg concentrate intake (Roth et al., 2009), or 8 to 41 days to consume just 40 grams (Neave et al., 2018b). This has led to individualised weaning techniques being developed; Roth et al., (2008, 2009) and de Passillé and Rushen (2016) used data driven weaning approaches that utilise automated milk and concentrate feeders to enable weaning based on a target concentrate feed intake. This results in a large variance of the age at which calves are weaned, from 45 to 98 days (Roth et al., 2009) and 58 to 94 days (de Passillé and Rushen 2016). It appears that there are factors beyond milk and feed availability that impact the success of weaning techniques as gradual weaning by lowering milk intake does not improve the performance of calves that showed lower feed intakes pre weaning (Bittar et al., 2020) and greater consideration of individual behaviour traits is needed. In the calf world there is an increased movement towards data driven farm management that considers the needs of the individual which enables improved welfare (reviewed by Rutten et al., 2013), and whilst opportunities to manage weaning individually using data-driven and technological approaches is commonplace on dairy cow farms, this technology is not utilised for goat kids due to the relatively low economic worth of each individual and high investment required for this technology. Therefore, to have real-world impact and provide recommendations that are feasible for implementation there is a need for research that identifies weaning improvements that are feasible for use on dairy goat farms.

2.4 Individuality and personality – the future of animal welfare?

The concept of animal welfare has evolved since it was first brought to scientific attention as a result of the Brambell committee “Report of the Technical Committee to Inquire into the Welfare of Animals Kept under Intensive Livestock Husbandry Systems,” published in 1965. This highlighted that farmed animals should have the freedom ‘to stand up, lie down, turn

around, groom themselves and stretch their limbs' which quickly became known as 'Brambell's Five Freedoms' (Brambell, 1965). In response to this government commissioned report the Farm Animal Welfare Council (FAWC – renamed the Animal Welfare Committee (AWC) in October 2019) was founded and was instrumental in the development of the 'Five Freedoms' framework (Figure 2-2) still used in academia, industry, and policy globally.

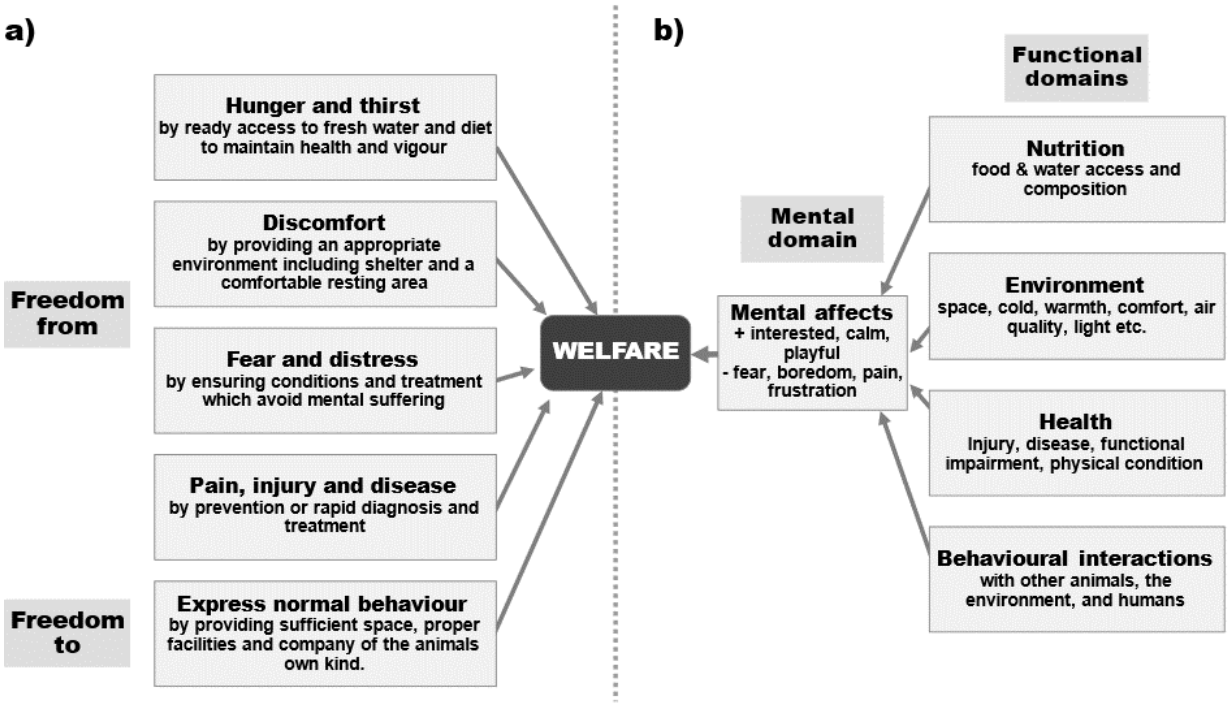


Figure 2-2. Comparing how the Five Freedoms (a) and Five Domains (b) welfare frameworks conceptualise animal welfare (Five Freedoms from Webster, 1994; Five Domains adapted from Mellor et al., 2020).

The Five Freedom framework's traditional focus of acceptable animal husbandry relating to minimising suffering has been increasingly critiqued for its lack of focus on affective states, ability to experience positive experiences, and consideration of individual or species-specific variation(Broom, 2011; Carenzi and Verga, 2009; Fraser, 1999; Fraser and Duncan, 1998; Mellor, 2016). The Five Domains model (Figure 2-2) has become favoured due to its consideration of mental state and comprehensive assessment of factors that influence overall welfare. The Five Domains model places emphasis on the differences between functional and affective states and has a greater degree of flexibility compared to the Five Freedoms which focuses on the absence of negatives (Figure 2-2). The Five Domains specifically considers how each functional domain has the potential to impact the mental domain positively or negatively in terms of affective states. Affective states are direct components of emotional experiences (psychological phenomena that influence behaviours: Beckoff, 2000). Affective states and the emotions that relate to them vary experientially and can be used as indicators of welfare (Jirkof

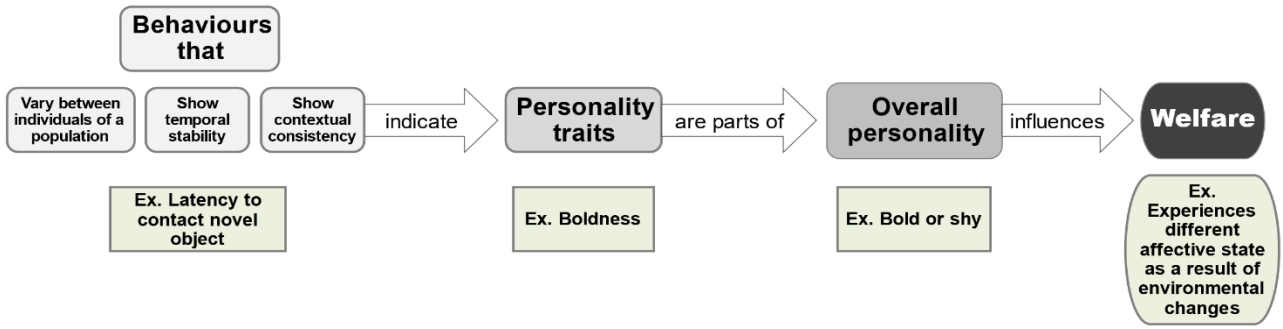
et al., 2019), and consideration should be given to the likelihood individuals will differ in their experience of the fundamental factors that impact affective states (Finkemeier et al., 2018).

2.4.1 Individuality and its association with personality

There is increasing evidence that demonstrates individual variation in the ability of animals to adapt to environmental changes, in their likelihood of developing a welfare problem, and in the type of problems they suffer from (Koolhaas et al., 2010). Differences in behavioural responses to stressors are sometimes referred to as 'coping styles' (Koolhaas et al., 1999), and typically individuals that experience more fear are those that exhibit stronger behavioural responses (Boissy, 1995). Individuality in behavioural responses has been reported across a range of farm animals from as early as 1988 (social modulation of pituitary-adrenal responsiveness and individual differences in behaviour of young domestic goats; Lyons et al., 1988), but only recently has the relationship between individuality and 'personality' traits begun to be formally explored. Over the last two decades attention has been paid to determine and define what a non-human animal 'personality' is (Kaiser and Müller, 2021) and whilst some terms are still used interchangeably (the word 'personality' is often overused in situations where 'individuality' is simply described), there is now consensus that 'personality' should be used to describe inter-individual behavioural differences that are temporally and contextually consistent (Koolhaas et al., 2010; Wolf and Weissing, 2012).

Farm animal personality is an important new research area, particularly as personality and coping style are likely related (Finkemeier et al., 2018) and further understanding of personality could help select individuals that can be housed in captivity without developing welfare problems (Richter and Hintze, 2019). This could be of particular commercial interest due to the heritability of traits such as reactivity and fearfulness being reported in farmed species (reviewed by Boissy et al. 2005), which is important for animal welfare considerations, but also as these traits link to productivity (Hemsworth et al., 2000).

An individual is considered to have a personality if: they show behaviours with inter-individual variation; the scores of each behaviour when measured repeatedly are correlated; and the scores of these behaviours show correlation and are displayed in different contexts (Figure 2-3: Kaiser and Müller, 2021)). The study of personality has revolutionised the field of behavioural and evolutionary ecology as increasing evidence that individuals within a population show fixed, inflexible and consistent behaviour has shifted research emphasis to individual rather than whole population work (Weiss, 2018). If farm animal welfare science is to ensure all animals have a 'life worth living' or 'a good life' then attention must be paid to all individuals within a group, something which has been historically lacking (Winckler, 2019). Therefore,



understanding inter-individual differences, their relationship to personality and how these differences impact other traits that affect overall welfare could advance the field considerably.

Figure 2-3. The relationship between behaviours, personality traits, personality and welfare with key criteria and examples (adapted from Kaiser and Müller, 2021).

There is mounting evidence that a variety of farm animal species meet these personality criteria, and that personality is related to production traits. A particularly well-researched body of evidence is accumulating regarding cattle; beef heifers who spent more time interacting with a novel object are more likely to be physically present at the front of the herd (Ramseyer et al., 2009) and dairy heifers offered a choice of different forages/flavours show varying amounts of exploratory feed sampling, with those that spent more time interacting with a novel object in a prior test having increased times exploring and eating novel feeds (Meagher et al., 2017). A recent review concluded that dairy cattle show stable personality traits within specific developmental periods (pre to post weaning then from puberty to lactation) but consistency is poor across puberty (Neave et al., 2020) – demonstrating that ontogeny stage is important to consider. Personality traits have also been linked to feed intake and growth of calves during weaning – calves showing higher exploration in a novel environment were faster to consume grain, had higher intakes, improved growth rates and visited the milk station fewer times post-weaning suggesting that they experienced a better weaning transition than others in the same group (Neave et al., 2018b); adding weight to the argument that tailoring early nutrition and weaning management to individual needs could improve welfare (Costa et al., 2019).

2.4.2 Evidence regarding goat individuality and personality

Goat personality research has generally focused on adults with very specific research objectives; however, it has been demonstrated that goats do show personality traits that impact other variables. Finkemeier et al., (2022) found that 42 out of 95 adult dwarf goats (44.2%) were stable for the personality trait boldness and 32 (33.7%) for activity (as measured by open field and novel object tests repeated after 14 days), however no relationship was found between

personality and learning (using data from only the first OF and NO-test), but goats stable in the trait boldness showed a learning effect (with less bold goats outperforming bold goats in reversal learning tests: Finkemeier et al., 2022), demonstrating how personality research can be complex in its interpretation due to its multifactorial nature and the difficulties in examining these kinds of relationships for cause and effect. Nawroth et al., (2017) also found that personality was related to learning, identifying consistent personality traits (repeatable across 21 days) in 16 adult mixed breed goats with less sociable individuals performing better at visual discrimination than more sociable goats. Whilst these studies found short term test repeatability, longer term (14-16-month intervals) stability of responses has been reported in 16 adult mixed breed goats by Briefer et al. (2015) in the traits exploration and sociability which was found to explain variability in heart rates and suggested lower autonomic nervous system reactivity of social goats.

Some research has investigated the link between personality and feeding behaviours which would be highly relevant to understanding the weaning transition, however this work has focused on adults. Miranda-de la Lama et al., (2011) used the term ‘identity profiles’ as an umbrella term to cover individuality, personality and their relationships with morphological traits, of which their research identified four; ‘passive’ (submissive with no attempt to avoid or engage in agonistic behaviour), ‘avoider’ (submissive and avoided agonistic and non-agonistic behaviours), ‘aggressive (dominant and mediated other social conflicts), and ‘affiliative’ (average dominance rank and engaged in socio-positive behaviours. These ‘identity profiles’ had relationships with feed intake, passive goats spent the least time feeding, and avoider goats the most, (aggressive and affiliative goats were comparable in feeding times but intermediate to avoider and passive individuals) (Miranda-de la Lama et al., 2011), this could well relate to hierarchical factors associated with social groups, however there is no scientific literature to inform us on the relationships between individuality and hierarchy in ruminant species. Neave and Zobel (2020) reported similar results; identifying a relationship between personality (four-week repeatability) and feeding behaviour of 13 adult female dairy goats, with bolder goats showing higher aggression and fearful goats less aggression and lower feeding time. A relationship between personality and feeding seems an especially important consideration when attempting to understand how goat kid behaviour and welfare is affected by the weaning transition.

There has been some work with goat kids to understand their responses to different novel objects, animals and environments, but few have tested this in a way in which meets the criteria for assessing personality laid out by Kaiser and Muller, (2021). There is a notable lack of repeated tests to assess temporal stability – instead research has focused on assessing behavioural indicators of fearfulness at one point in time. It is well documented that individuals

differ in the level of fear they display in response to a stressor, with more fearful individuals showing stronger behavioural responses (Boissy, 1995), and often decreased productivity (Hemsworth et al., 2000), and the heritability of fear has been reported in farmed species (reviewed by Boissy et al., 2005). Tests for fearfulness have been criticised for their poor validation, unclear reliability, and inconsistent methodology (Forkman et al., 2007), factors that make it difficult to generalise results, therefore further investigation of goat kids' responses to fearfulness is important to further understand validity. Differing fear responses have been reported in five-week-old goat kids in their responses to separation, and reaction to familiar and unfamiliar goat kids (Chojnacki et al., 2014). The kids in this study were born to dams whom experienced experimentally manipulated stocking densities during pregnancy (low density n=18; medium density n=16; high density n=16) and it was found that kids from dams with highest prenatal stocking densities (higher stress levels) showed greater levels of fear (more escape attempts during separation) (Chojnacki et al., 2014). However, due to the lack of repeated testing nothing can be extrapolated regarding personality of these juvenile goats.

Further work on goat kids has aimed to identify how rearing method affects goat kids' behavioural responses to a variety of fear related tests. Winblad von Walter et al., (2021) used kids either reared artificially (n=10), separated from their dams during the day (n=6) or fully dam reared (n=6) at eight weeks of age, and concluded that dam-reared kids showed the least behavioural responses with day-separated kids showing the highest stress responses. However, the methodology of this study made a number of choices that were critiqued by a critical review of fear tests (Forkman et al., 2007), with the tests being performed consecutively with multiple stressors being combined – kids were subjected to consecutive isolation and arena tests, with an auditory stressor (a dog bark) added to the isolation test and a novel object added to the arena test. Furthermore, the tests also seemed very long compared to other studies (two minutes per test, Chojnacki et al., (2014); five minutes per test, Finkemeier et al., (2019); three minutes per test, Toinon et al., (2021)) with the novel arena test lasting for a total of twenty minutes, there is also reason to be cautious of possible ceiling effects of cortisol and heart rate (Veissier and Boissy, 2007) with such prolonged exposure to multiple fearful stimuli. Additionally, all of these kids were likely subject to group reflects and issues of pseudoreplication as the artificially reared kids were kept in one pen, whilst the partially separated and fully dam reared kids shared a pen throughout. Whilst the statistical model included the effect of rearing system it did not account for the two groups being housed together.

In a similar study Tonion et al., (2021) performed consecutive novel arena, novel goat and novel object tests (each lasting three minutes) on female Saneen kids between 30 and 39 days of age to investigate differences between artificially (n=20) and dam reared (n=20) kids. These kids were initially kept in a single pen for each treatment, then at weaning were mixed

into one large pen with kids weaned on the same day; it is possible that the early life experience within each individual treatment pen could have impacted the kids later behavioural responses however as there were no pen replicates it is impossible to consider this as it is accounted for by each treatment. There was a further familiar human test that was conducted on the group level. During these tests artificially reared kids displayed more active behaviours and vocalisations whilst dam reared kids self-groomed and urinated more, there were no differences in cortisol but overall they suggest that artificially reared kids show a higher behavioural arousal indicative of a more active coping strategy during challenging situations and that overall artificially reared kids were bolder and less neophobic (Tonion et al., 2021). Whilst the authors state the differences remained 'relatively consistent' across tests (Tonion et al., 2021) there were no test-retest repeatabilities and they were therefore unable to make definite conclusions on coping style or personalities.

Only one study has reported results for goat kids of repeated tests that could meet the criteria for personality – Finkemeier et al. (2019) reported behaviour consistency in repeated standardised tests in 61% of 108 juvenile dwarf goats tested at eight and ten weeks of age and identified 'boldness' and 'activity' as personality traits. Activity was found to be positively correlated with heart rate variability and overall weight gain, but neither trait was linked to dominance status (Finkemeier et al., 2019). We know that there are high variations between kids in terms of their growth rates (Deeming et al., 2016), whilst there are likely numerous factors that contribute to this, personality or individuality has not been fully explored. As mentioned in section 2.3.2. of this literature review, feeding and weight related individuality is beginning to be considered in on-farm management techniques where the technology exists to enable it (individualised weaning of calves: Benetton et al., 2019; Welboren et al., 2019), but very little research has focused on this area within goat kids. This is an important area for future research, particularly as Richter and Hintze, (2019) stated within their review that explicit consideration of unique individual features could advance animal welfare science.

2.5 Conclusions

As has been demonstrated throughout this literature review, there is an overall dearth of literature that has focused specifically on goat kids during the milk feeding stage and weaning transition, which is particularly noticeable when compared to the extensive research that has been conducted with dairy calves. The key areas that have been highlighted in each section of this literature review and were therefore investigated by this thesis relate to the following priority areas.

To understand on-farm productivity and welfare, an important first step is to identify, quantify and prioritise concerns (Whay, 2007). To be able to do this and develop an

understanding of the possible welfare and productivity challenges for a specific species first the systems in which they are kept must be quantified, and the husbandry practices used for their management. These initial investigations are essential to allow for the understanding of a species responses to different management systems to be developed, and for future research to then be suitably targeted. Currently we have very limited information on how farmers conduct weaning with the surveys by Anzuino et al. (2019) and Hemsptead et al. (2021) collecting no data on the physical method of weaning. Bélanger-Naud et al. (2021) collected the most detailed information on weaning that is currently available, finding that 39% of a sample of commercial dairy goat farmers based in Canada used abrupt weaning, with 61% using a progressive gradual strategy. Further detailed information on this subject will help researchers to understand how best to improve the weaning transition which is a high-risk stage of management for kid welfare and productivity. Whilst there has been recent survey work aiming to understand current management of goats (Anzuino et al. 2019; Hempstead et al. 2021), these have primarily focused on adult lactating does on commercial dairy goat farms, with limited information collected about youngstock management aside from the farmer-reported survey by Bélanger-Naud et al. (2021) which focused on commercial dairy goat-kid rearing practices in Canada. This lack of understanding of practices currently being utilised by farmers to rear goat kids away from their dams and how willing farmers would be to change their practices informed Objectives 1 and 2 of the thesis.

Whilst there is extensive research on calf feeding behaviour in both natural and artificial rearing conditions, limited information is available for goat kids (milk feeding and weaning was last reviewed by Lu and Potchoiba, 1988). Implications of current management such as lack of experienced social models may be especially impactful on the weaning transition as it occurs far earlier than under natural conditions (UK standard is 56 days; Anzuino et al., (2019), compared to 3-6 months naturally; Collias, 1956) and relies on sufficient intake of solid feeds to make up for the loss of milk nutrients (Baldwin et al., 2004). Increasing our knowledge of the development of both milk and solid feedstuff feeding behaviour under commercial artificial rearing conditions could have implications for management, particularly around understanding goat kid individuality and improving the weaning transition. The lack of species-specific research must be addressed in order to fully understand how goat kid feeding behaviour develops during the milk-feeding and weaning stages, and how they use an ad libitum milk feeding system, as this may have implications for their management. Currently, we simply do not know what affect ad libitum milk feeding systems have on the feeding behaviour of goat kids, with no research having quantified their intakes during this time, therefore Objective 3 aimed to fulfil this gap by characterising the development of the behaviour of goat kids reared artificially.

Overall, there is clear body of evidence from dairy calves that indicates that abrupt weaning from a high milk intake results in individuals unable to sufficiently consume enough solid feeds to compensate for the sudden loss of milk nutrients which results in individuals that experience poor growth (Jasper and Weary, 2002) and prolonged hunger (de Passillé et al., 2011) which is experienced as a negative affective state detrimental to their welfare (Mellor et al., 2020). Whilst gradual weaning techniques have been evidenced as improving overall productivity and welfare (Budzynska and Weary, 2008; Scoley et al., 2019) this appears to vary on an individual basis (Bittar et al., 2020; de Passillé et al., 2011; Roth et al., 2009) and this inter-individual variation is only in the early stages of investigation (Neave et al., 2018ab). Whilst there is limited goat-specific research to support this as kids are not typically fed on limited meal-based intakes, we can presume that due to possessing the same ruminant physiology findings are likely to transfer between species. A smooth transition from a liquid milk diet to one reliant on nutrition obtained from solid feedstuff is essential to support future post weaning growth which influences future productivity, and any strategies that aim to improve this transition will be beneficial to the dairy goat industry. Whilst gradual weaning research is extensive for calves, this literature focuses on individualised methods that rely on technology (such as computerised feeders that step-down individual milk allowance) not currently utilised on goat farms, and therefore currently has limited applicability. Consequently, there is an obvious need for applied research on the most feasible ways to increase solid feed intake, and efficiency of the weaning transition of artificially reared goat kids which informed Objective 4, by trialling feasible strategies to improve the weaning transition of artificially reared goat kids.

Currently there are major knowledge gaps in our understanding of how individuals' coping abilities differ, and this appears to be especially impactful in periods where animals are expected to cope with stressful management practices and changes to their living conditions. This is highly relevant to artificially reared goat kids whom over a relatively short period of time are separated from their dams, experience major social environment changes, must adapt to a new feeding system, and undergo stressful procedures such as disbudding, castration, and weaning. Whilst personality research may be a developing field for production animals, it has been well demonstrated in the literature that physiological stress responses vary considerably and therefore it seems likely that there are underlying traits modulating this. If these can be uncovered and explored, an increased understanding of which individuals cope best under commercial conditions could be established and may result in an ability to tailor management to individual's needs. However, this field is in an early stage of research, and therefore the methodology and interpretation of tests that aim to establish these 'personality' traits needs further species-specific work to ensure the way we measure them conforms to the fundamental

principles of sciences; that of repeatability, validity, and reliability. Subsequently Objective 5 was designed to develop this methodology to evaluate the individuality of goat kids.

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3. Rearing goat kids away from their dams 1: A survey to understand rearing methods

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It is estimated that the first author H M Vickery contributed approximately 85% of the work including conceptualization, producing and distributing the survey, analysing results and fully preparing the first draft. Authors R A Neal and R K Meagher provided supervision, assistance finalising the methodology and provided review and editing of the written paper draft.

3.1 Abstract

Despite an estimated global goat population of over one billion, little is known about methods being used to feed milk to artificially reared kids (reared away from their dams) and how kids are weaned from these systems. Quantifying and characterising current methods utilised on farms will enable future targeted research to investigate best practice methods for milk feeding and weaning of artificially reared kids. A recall-based survey that investigated on-farm kid-rearing practices (focusing on the milk feeding and weaning stages) was distributed via social media, and regional goat organisations across multiple countries. 242 responses from 16 countries were collected and geographically grouped. Responses that could not be grouped sufficiently were removed (9 responses from 8 countries). 233 responses from 8 countries (United States of America (USA) 72; United Kingdom (UK) 71; Australia 33; Canada 23; New Zealand 20; European Union (EU) 14), were analysed. Most farms (217; 93%) bred their own kids. The most common milk feeding method was meal-based 'bottle' feeding, used on 135 farms (57.9%), followed by *ad libitum* feeding used by 72 (30.9%). A relationship between number of kids reared and feeding system was identified, $\chi^2(3, N = 233) = 89.605$, $p < 0.001$, with farms rearing >100 kids more likely to feed milk *ad libitum*. 170 farms (72.9%) weaned based on a target age and 85 (36.4%) on a target weight, 53 (22.7%) used both and 45 (19.3%) neither. Target weaning ages and weights varied across countries; median age was 84 days (interquartile range (IQR) 56-84), and median weight was 16 kilograms (IQR 15-18). A difference was found between milk feeding system for weaning method ($X^2(2, N = 232) = 63.797$, $p = <0.001$), with kids most likely to be abruptly weaned from *ad libitum* systems (or gradually weaned from bottle feeding). Abrupt weaning was used by 67 farms (28.8%), and gradual weaning was used by 165 (71.1%). Gradual weaning strategies included reducing milk quantity (150 farms; 93% of farms providing detail) and diluting milk (6 farms; 4%). 169 (72.5%) supplied enrichment that met the survey's definition; items to climb on/hide in were most common, provided by 157 farms (92.8%). Findings suggest differing practices in smaller-scale bottle-fed versus larger-scale *ad libitum* milk systems, likely reflecting differing system needs. This highlights a requirement for welfare focused research in kids reared artificially in order to identify and communicate best practices to ensure on-farm welfare is optimised within each system.

3.2 Introduction

Goats may have been the first farmed ruminant species (Hatziminaoglou and Boyazoglu, 2004), having been domesticated approximately ten thousand years ago (Zeder and Hesse, 2000). They are a versatile species, adaptable to many environmental conditions, and since their domestication have become popular across the globe (Morand-Fehr et al., 2004). The global population was estimated to stand at over one billion in 2018, an increase of 15.9% over a ten-year period (FAOSTAT, 2020). Globally, milk producing goat numbers have increased by 20.6% from 2008-2018 (FAOSTAT, 2020). Despite only owning 4.2% of the world milk producing goat herd, Europe produces 14.6% of global goat milk (FAOSTAT, 2020), indicating the region's intensive industry and husbandry practices, which could impact animal welfare. Global statistics often do not include home consumption or informal milk sales where records are not kept (Miller and Lu, 2019), therefore the global goat industry is likely to be larger than currently estimated.

Despite this popularity, documented information about the characteristics of goat production systems and the welfare of the animals within them, either regionally or globally, is scarce. A review by Morand-Fehr et al., (2004) highlighted that basic research related to goat farming, such as understanding systems of production and 'proposing methods and know-how acceptable to farmers' should be a priority, and nutrition, genetics and reproduction were the main scientific topics of papers presented during the International Conference on Goats, with concerns being expressed over the low applicability of this research to commercial farms (Morand-Fehr and Lebbie, 2004), and peer-reviewed goat-specific research applicable for use on-farm is still limited, particularly for youngstock. Therefore, to have the largest impact, it is essential that research aiming to improve kid welfare is targeted and feasible for application on farms.

The milk feeding stage and weaning transition are considered high risk periods for young ruminants, with the highest mortality occurring in these first months of life (Buddle et al., 1988; Todd et al., 2019). During the milk feeding stage young ruminants digest milk in their abomasum and to be successfully weaned must develop a functioning rumen capable of microbial fermentation, which is a large physiological change (Baldwin et al., 2004). Rumen development is linked to the ingestion of solid feedstuff and low consumption is correlated with slower rumen development and subsequent weight loss post weaning (Khan et al., 2007; Sweeney et al., 2010). Under natural conditions weaning would take place over an extended time frame involving a gradual reduction in the intake of milk and contact with the dam (Bungo et al., 1998) alongside increasing solid feed consumption weaning from artificial milk supply systems cannot incorporate these natural cues (such as allelomimicry and dams preventing access to milk) and can cause responses indicative of stress (Greenwood, 1993; Lu and

Potchoiba, 1988). Therefore, weaning management in commercial systems is an important potential welfare issue. Yet the prevalence of different goat kid-rearing systems, and development of optimised youngstock husbandry practices have garnered limited research attention.

A recent survey circulated in the United Kingdom (UK) by the industry group the 'Milking Goat Association' highlighted the lack of knowledge surrounding current husbandry practices, and that research on factors affecting kid health were a top priority for farmers (Anzuino et al., 2019). The survey found that 85% of the responding farmers were feeding milk *ad libitum* and that age and weight were common criteria for weaning decisions, a finding supported by a smaller study of 16 farms in New Zealand (Todd et al., 2019). However, the actual methods of weaning from milk were not investigated within either publication. In calves, it has been found that weaning method can influence growth rates and impact welfare (Roth et al., 2009; Weary et al., 2008) and understanding on-farm weaning practices could inform applied research to improve kid welfare.

The aim of this survey was to expand on the information presented by Anzuino et al. (2019), by collecting detailed information about on-farm kid-rearing practices from a greater range of farmers across multiple target countries. The survey was designed to collect information on milk feeding strategies, solid feed introduction, weaning methods, and environmental enrichment provision as well as key farm characteristics. Preliminary results of this survey have been published in abstract form (Vickery et al., 2021). Quantifying rearing methods currently being used will enable future research to be suitably targeted at investigating best practice methods for milk feeding and weaning of artificially reared goat kids, in order to optimise goat kid welfare.

3.3 Material and methods

3.3.1 Questionnaire

A questionnaire was designed, for collecting anonymous responses, and consisted of 29 questions, some with multiple parts, across two main sections. The first section focused on background information, milk feeding strategies, feeding management, and weaning management (Appendix 1). The results of this first part of the survey are reported here. Multiple choice questions (with pre-defined answers) that allowed for quantitative data analysis were combined with open-ended questions that enabled a greater level of detail in the responses. The survey was designed to be completed from memory within ten minutes. Routing meant that respondents did not have to answer all questions but were directed to sections specific to their milk feeding system and weaning method. Five farmers were asked to read and

comment on a pilot version, which resulted in minor changes to question format including multiple choice options. The survey was available in English and translated into Dutch and French. The translations were checked for accuracy by back translation into English, and clarification of specific words was sought from native speakers.

3.3.2 Participation criteria and recruitment

The survey was distributed widely to encourage a range of farmers to participate and the greatest possible participation from parts of the world where goats are commonly farmed in large scale systems for commercial production. The only criteria for participation was that the respondent must be raising milk-fed goat kids artificially (away from their dams), and that only one response per farm was submitted. Participation was voluntary and no incentive was offered for submitting a response.

The researchers' presence within the UK was utilised to encourage greater response rates by distributing paper copies, to farmers at the Milking Goat Association Open day (12th September 2019), the Goat Veterinary Society conference (10th October 2019), and the Dairy, Sheep and Goat Conference (27-28th January 2020). An electronic version of the questionnaire was created in the JISC Online Survey format and an introductory email with a link to the online questionnaire was sent to relevant organisations globally (such as regional goat societies and veterinary services), who were asked to distribute the link within their membership base. A public post was created on the researchers' social media (Facebook & Twitter) with a link to the questionnaire, to encourage further participation. Whilst a large number of responses from English speaking countries was anticipated, translations to Dutch and French were created to assist in gathering responses from Netherlands, France and Canada where commerical goat production is prevalent. The English version was available online from 21st September 2019 to 30th April 2020, the French from 13th January to 15th June 2020, and the Dutch from 30th January to 15th June 2020.

3.3.3 Statistical analysis

JISC online survey responses were downloaded and collated in Microsoft Excel. Open text responses were thematically analysed and coded based on the contents. Statistical analysis was then conducted in IBM SPSS (version 25; SPSS Inc., Chicago, IL, USA). Most results are presented as simple summary statistics. Comparisons were made for nominal-to-nominal variables using Chi-square tests (milk feeding system by weaning method and type of gradual weaning) and Kruskal-Wallis tests for nominal to ordinal variables (number of kids reared by milk feeding system and weaning method).

All weights stated were converted to kilograms (kg), and ages were converted to days; when a range was given, the median was used for analysis. Open text responses described the enrichment provided and based on these descriptions it was subsequently decided whether the description met the survey's definition of enrichment. They were then classified into enrichment types and levels of scientific evidence.

3.4 Results

3.4.1 Survey exclusions and response

A total of eight surveys (three paper, five online) were excluded for reasons of incomplete responses, responses for dam reared kids, or responses for incorrect species. After removals, 14 paper copies were uploaded. The English online version received 212 responses from 16 countries, the Dutch version one response from The Netherlands, and the French version 15 responses (eight from France and seven from Canada). Responses were then grouped geographically and responses from countries or regions that could not be sufficiently grouped into categories of >10 were removed (9 responses from 8 countries: South Africa (2), Thailand, Nigeria, Indonesia, Guatemala, Iran, Portugal and Jamaica). A European Union (EU) category with 14 responses (2 from the Netherlands, 3 from Ireland and 9 from France) was created. Final analysis was conducted on 233 responses from 8 countries, giving an overall total of 233 surveys included in the analysis (Table 3-1).

Table 3-1. Survey response per country by number of goat kids reared artificially (away from their dams) (n=233).

Country	Number of responses n (%)	Average number of kids reared per year n (%)						
		<20	20-50	51-100	101-200	201-400	401-600	>601
USA	72 (31)	36 (50)	23 (32)	8 (11)	2 (3)	2 (3)	0 (0)	1 (1)
UK	71 (30)	31 (44)	10 (14)	3 (4)	8 (11)	6 (8)	7 (10)	6 (8)
Australia	33 (14)	15 (45)	10 (30)	3 (9)	1 (3)	1 (3)	1 (3)	2 (6)
Canada	23 (10)	8 (35)	2 (9)	2 (9)	4 (17)	5 (22)	0 (0)	2 (9)
NZ	20 (9)	10 (50)	3 (15)	4 (20)	0 (0)	0 (0)	0 (0)	3 (15)
EU[1]	14 (6)	2 (14)	1 (7)	0 (0)	5 (36)	4 (29)	2 (14)	0 (0)
Total	233	102 (44)	49 (21)	20 (9)	20 (9)	18 (8)	10 (4)	14 (6)

Abbreviations: USA: United States of America; UK = United Kingdom; NZ = New Zealand; EU = European Union
[1]EU responses include 2 from the Netherlands, 3 from Ireland and 9 from France.

3.4.2 Key farm and system characteristics

Table 3-1 presents survey responses by country and number of kids reared and shows that most responses were collected from farms rearing <50 kids. Most farms (217, 93.1%) bred their own kids, 12 (5.2%) brought in kids to rear, and four (1.7%) both bred and brought in kids. Of those who brought in kids, nine (66.7%) collected them at <7 days old, two (13.3%) at 8-14 days and the remaining three at >15 days. Farms were asked to select the approximate percentage of kids they reared that were female; 25 (10.7%) were only rearing females, 59 (25.3%) were rearing 80%, 136 (58.4%) were rearing 50%, five (2.1%) raised 20% females, and the remaining eight (3.4%) reared no females at all. The purposes for rearing kids are presented in Figure 3-1.

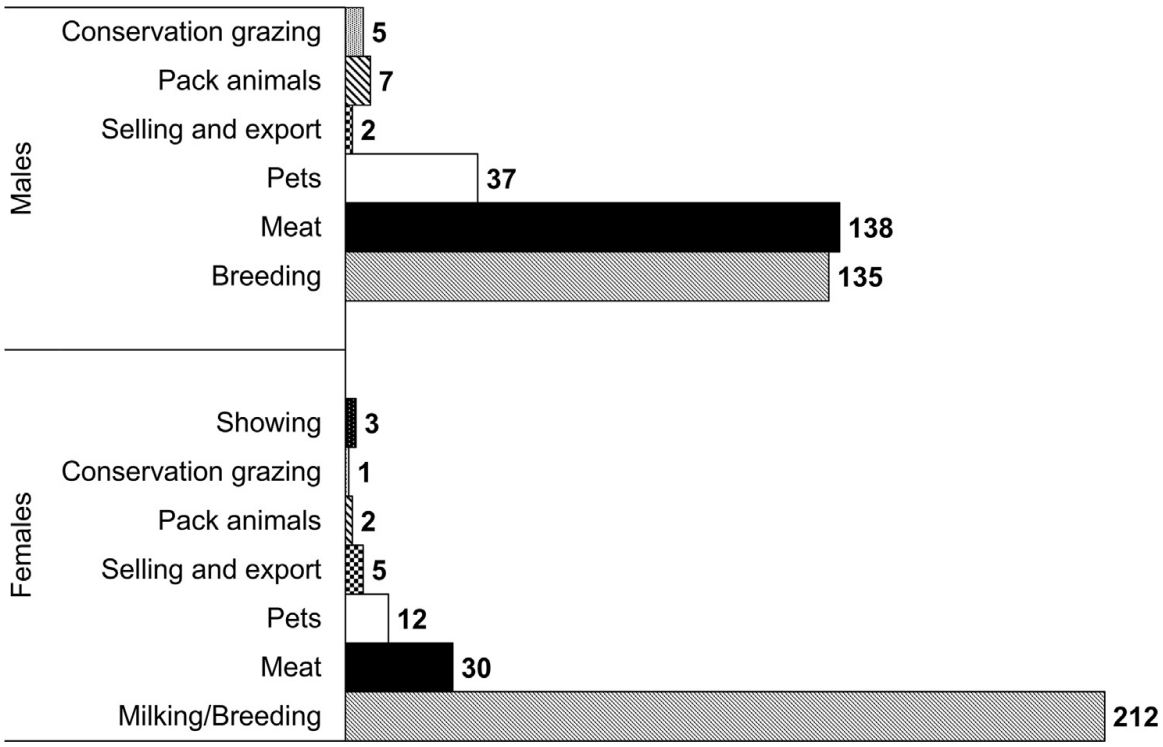


Figure 3-1. all stated purposes for rearing male (*n* = 208 participants) and female (*n* = 225 participants) goat kids.

3.4.3 Milk feeding systems

Table 3-2 provides details on each of the systems used to feed milk to artificially reared goat kids. A statistically significant difference between number of kids reared and feeding system used was identified, $\chi^2(3, N = 233) = 89.605$, $p = <0.001$. Dunn's pairwise tests ($p = 0.001$, adjusted using the Bonferroni correction) showed there was significant evidence of a difference between farms rearing >100 kids compared to <20 kids, 21-50 kids, and 51-100 kids, with those farms rearing <100 kids more likely to use bottle feeding and those rearing >100 kids more likely to use *ad libitum* milk feeding. There was no evidence of a difference between other pairs.

Table 3-2. Systems used to feed milk to artificially reared goat kids (total n = 233).

Milk feeding system management	Total number of respondents	Respondents in category: n (%)
Part A: Bottle feeding[1]	233	135 (57.9)
Number of milk meals per day at 8 days of age	*130*	
6x		7 (5.4)
5x		8 (6.2)
4x		62 (47.6)
3x		40 (30.7)
2x		13 (10.0)
Does the meal frequency change after 8 days?	124	
Yes		111 (89.5)
No		13 (10.5)
Minimum number of milk meals per day if decreased after 8 days:	88	
3x		1 (1.1)
1x		87 (98.9)
Part B: Ad libitum milk feeding[1]	233	72 (30.9)
Type of *ad libitum* milk feeder used:	72	
Förster-Technik		27 (37.5)
Homemade		12 (16.6)
Bucket/bar		9 (12.5)
Britmix		4 (5.5)
Other		20 (27.7)
Number of kids per ad libitum milk teat:	72	
<5		27 (37.5)
6-10		28 (38.8)
11-20		15 (20.8)
>21		2 (2.8)
Part C: Other milk feeding (open text)[1]	*233*	*26 (11.2)*
Description of feeding system:	26	
Bucket/bar type		17 (65.3)
Boiler with teats		2 (7.6)
Modified *ad libitum*		2 (7.6)
Homemade		1 (3.8)
Bottles		1 (3.8)
Combination of methods		1 (3.8)
No description		2 (7.6)

[1]The survey responses have been divided into three types of milk feeding, Part A shows information regarding bottle feeding, Part B *ad libitum* feeding, and Part C the 'other' strategies used.

3.4.4 Feeding and Weaning management

Feeding management practices are presented in Table 3-3 and show that most farms provided access to solid feed and forage at <14 days of age, but that both solid feed and forage type were variable.

Table 3-3. Feeding management of artificially reared goat kids during the milk feeding stage (total n = 233).

Feeding management		Total number of respondents	Respondents in category n (%)	Median age first given (days)	IQR[1]
Is forage provided?		233			
Yes			229 (98.2)	7	1-14
No			4 (1.8)		
Type of forage fed		233			
Hay	As singular source		137 (58.7)		
	In combination		42 (18.0)		
Straw	As singular source		21 (8.8)		
	In combination		41 (17.2)		
Haylage	As singular source		4 (1.7)		
	In combination		15 (6.3)		
Silage	As singular source		3 (1.3)		
	In combination		0 (0)		
Natural pasture/ browse	As singular source		2 (0.8)		
	In combination		22 (9.4)		
Other[2]	As singular source		1 (0.4)		
	In combination		7 (3.0)		
Is solid feed provided?		233			
Yes			223 (95.7)	14	7-20
No			10 (4.3)		
Type of solid feed		233			
Commercial complete			187 (83.9)		
Home blend			36 (16.1)		
Species designed for[3]		133			
Caprine			53 (40)		
Bovine			45 (33.3)		
Ovine			26 (19.3)		
Equine			8 (6.7)		
Rabbit			1 (0.7)		

[1] IQR = Interquartile Range
[2] Other: alfalfa (2), chaff (2), Lucerne (2), Tree hay (1), Silage based total mixed ration (1)
[3]Species designed for was identified when respondents gave details of the manufacturer/feed name in their open-text response

In terms of weaning practices, most farms that used a target weaning age or weight gave a single set target (Table 3-4), eight gave separate target weaning ages for males/females or kids reared for different purposes, four used weight related to birthweight as an aim (2x, 2.5x, 3x, and 4x birthweight), one had separate target weights for male and female kids, and one aimed for 50% of their target 12-month weight.

Table 3-4. Strategies for deciding when to wean artificially reared goat kids from milk (total n = 233).

Country	Do you use a target age?	Target age (days)	Do you use a target weight?[1]	Target weight (kg)	Do you use both a target age & weight?
	Yes n (%[2])	Median (IQR)	Yes n (%[2])	Median (IQR)	Yes n (%[2])
USA	55 (76.4)	84 (70-84)	16 (22.2)	18 (15-23)	8 (11.1)
UK	37 (52.9)	56 (42-84)	25 (35.7)	15 (15-15.88)	13 (18.6)
Australia	29 (87.9)	84 (66.5-91)	8 (24.2)	16 (12-20)	8 (24.2)
Canada	19 (82.6)	56 (56-84)	14 (60.9)	15.5 (14.25-16)	11 (47.8)
NZ	13 (65)	98 (84-168)	9 (45)	20 (18-25)	5 (25)
EU	8 (57.1)	60 (56-72.5)	13 (92.8)	16.5 (16-17.5)	8 (57.1)
Total	170 (72.9)	84 (56-83)	85 (36.4)	16 (15-18)	53 (22.7)

Abbreviations: USA: United States of America; UK = United Kingdom; NZ = New Zealand; EU = European Union; IQR = Interquartile range
[1]Without further detailed information regarding breeds and production systems, weights can only be considered a broad indication.
[2]Percentages displayed are of total respondents for each country, presented in Table 1.

Weaning methods are presented in Table 3-5. A significant association was found between milk feeding system and weaning method ($X^2(2, N = 232) = 63.797$, $p = <0.001$), with kids most likely to be abruptly weaned from *ad libitum* milk feeding systems (or gradually weaned from bottle feeding). Weaning methods broken down by country, feeding system and number of kids reared are displayed in Figure 3-2. No significant association was found between milk feeding system and method of gradual weaning ($X^2(2, N = 156) = 13.318$, $p = 0.346$).

Table 3-5. Strategies for weaning artificially reared goat kids from milk (total n = 232).

Weaning strategies	Total number of respondents	Respondents in category n (%)
From bottle feeding	134[1]	
Abruptly weaned		19 (14.2)
Gradually weaned		115 (85.8)
From ad libitum feeding	72	
Abruptly weaned		48 (66.7)
Gradually weaned		24 (33.3)
From other feeding	26	
Abruptly weaned		0 (0)
Gradually weaned		26 (100)
Gradual weaning strategy used	152	
Reduction in milk quantity		142 (93.2)
Dilution of milk		5 (3.7)
Reduction in quantity & dilution		2 (1.2)
Other[2]		3 (1.9)
Time frame gradual weaning occurred over	116	
<7 days		12 (10.9)
8-14 days		17 (14.3)
15-21 days		7 (5.9)
22-28 days		17 (14.3)
>29 days		63 (54.6)

[1]One farm did not wean from bottle feeding and kept their kids on one milk meal a day indefinitely.
[2]Other: One combined milk quantity reduction and milk temperature reduction; One reduced milk temperature then provided water through the feeding machine at night for three days, and one full day; one gradually increased the number of kids per *ad libitum* teat before complete milk removal.

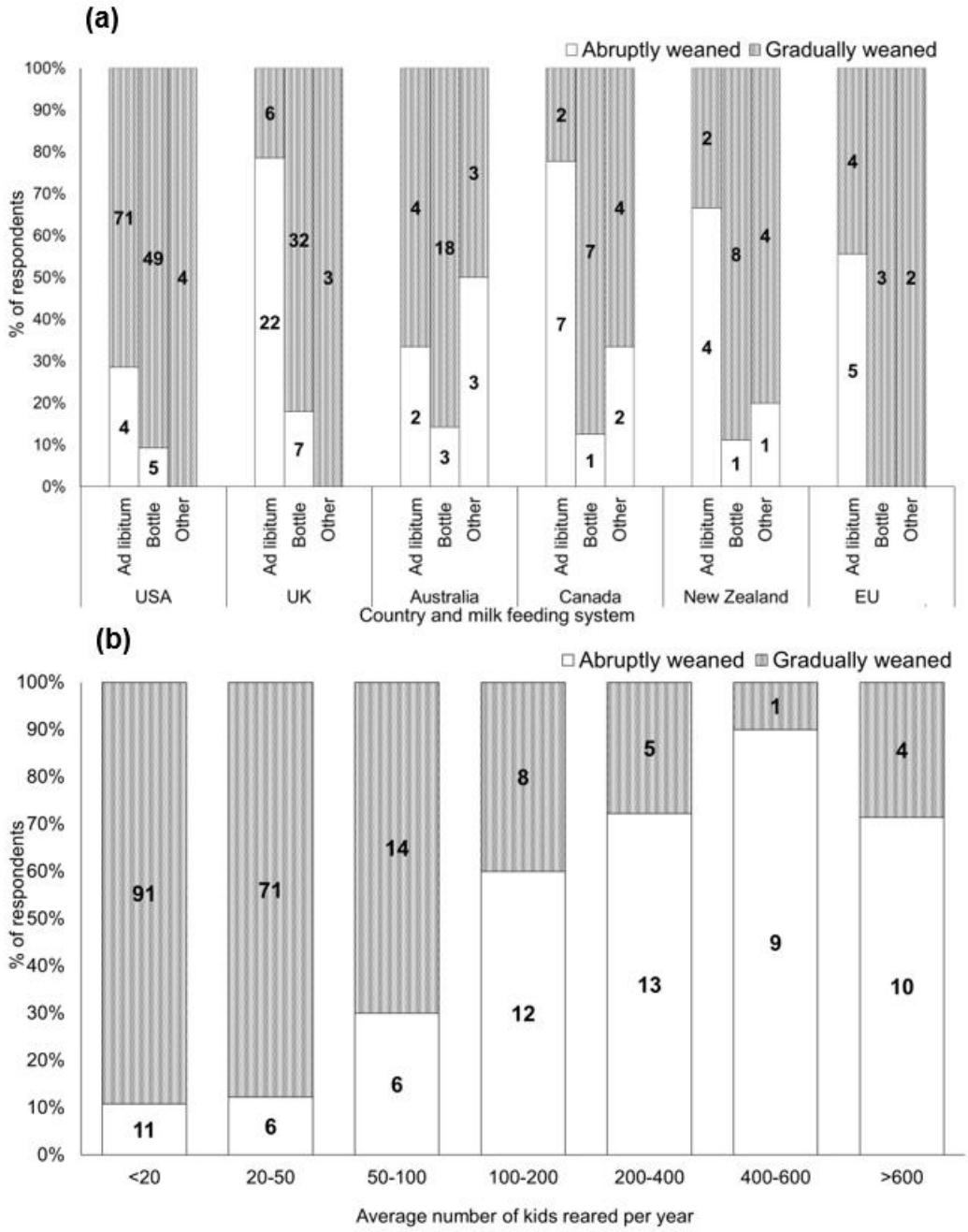
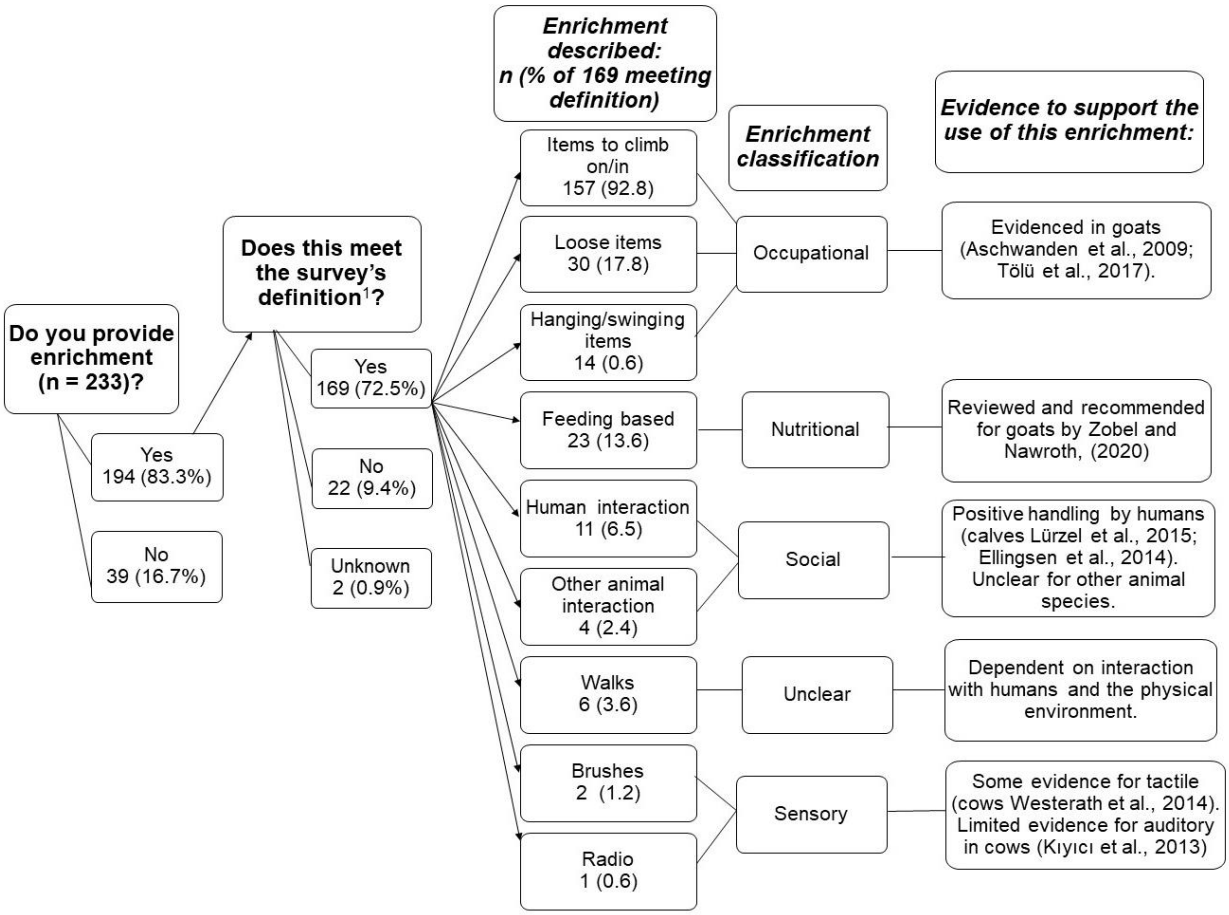


Figure 3-2. Goat kid weaning method by milk feeding system and country (a) or by number of kids reared per year (b). Actual n is represented on the bars (total n = 233).

A significant difference was identified between number of kids reared and weaning method used, $\chi^2(3, N = 232) = 58.380$, $p = <0.001$. Dunn's pairwise tests (p 0.001, adjusted using the Bonferroni correction) showed there was significant evidence of a difference between rearing >100 kids compared to <20 kids, 20-50 kids, and 50-100 kids. With those rearing >100 kids more likely to abruptly weaned.

3.4.5 Environmental enrichment

Figure 3-3 shows responses to questions regarding the provision of environmental enrichment, and classification of common enrichment types.



[1] Definition given: 'Environmental enrichment is defined as any item(s) or stimuli that you have provided beyond what is standard management, with the aim of improving the welfare (that is, the physical or psychological well-being of your kids)'. Responses not considered to meet this were those that described standard management, such as the provision of vitamin/minerals, identity tags or pasture access.

Figure 3-3. Environmental enrichment reported by farmers as being provided to artificially reared goat kids and the evidence for its use (total n = 233).

3.5 Discussion

3.5.1 Key farm and system characteristics

Responses were collected from multiple countries, with the UK and United States of America (USA) making up the largest proportion of respondents. Numerous responses were received from smaller farms (Table 3-1), possibly due to the sharing of social media posts into specific goat keeping groups, and therefore the results are skewed towards those raising a small number of kids each year. This survey identified a significant relationship between the number of kids reared per year and the milk feeding system used, with larger farms more likely

to *ad libitum* milk feed. This relationship may affect other aspects of kid management and including data from those farms rearing a small number of kids artificially is therefore important since they may require different management strategies. Collecting data from a wide range of farm sizes and purposes highlights the diversity that exists within the goat sector and a need for further research to be differentially targeted according to herd size. This study was limited by the length of survey employed, it is recommended that future research considers a wider range of sociodemographic factors relating to both human variables (education level, gender, employment status etc.) and animal variables such as genetics; this information could aid further understanding of factors impacting on-farm management.

3.5.2 Milk feeding systems

A previous survey of UK dairy goat farmers found that all but one farm raised kids without suckling from their dams (Anzuino et al., 2019). Information on artificial milk feeding systems is limited and currently focuses on large-scale commercial farms within the dairy industry, however, kids are reared artificially in non-dairy systems for a multitude of reasons including those related to management, rejection by the dam, multiple births, and mastitis. As the aim of this survey was to quantify current on-farm rearing methods for welfare research to be suitably applied, goats being reared artificially for any purpose (Figure 3-1) were included. Milk feeding systems could be impacted by housing management, including regional variation in common facility styles, and whilst not an objective of this survey, this is an area that could be investigated in further detail.

Despite the prevalence of goat kids being reared artificially, little research exists surrounding optimal milk intakes and methods of feeding milk after the colostrum feeding stage (last reviewed by Lu and Potchoiba, 1988). In Canada, *ad libitum* milk was fed on 55% of 104 farms (Bélanger-Naud, 2021) and in the UK, 85% of 46 farms (Anzuino et al., 2019); both were higher than found in the current survey. However, the respondents in both surveys were commercial dairy farms with median herd sizes of 190 (Bélanger-Naud, 2021) and 400 adult milking females (Anzuino et al., 2019), and whilst adult herd size was not collected in the current study, the majority (44%) of farms were artificially rearing <20 kids per year. The finding that those rearing larger numbers of kids were significantly more likely to use *ad libitum* milk feeding system could therefore explain this difference in the prevalence of *ad libitum* feeding between surveys.

High milk intakes such as those permitted by *ad libitum* systems have benefits including higher weight gains and increased natural behavioural expression (Jasper and Weary, 2002). However, of concern is the issue of one teat supplying multiple kids, and the related competition over access to milk. There are no studies specifically investigating the feeding behaviour of goat

kids reared on artificial milk supply systems, but in calves reduced access to milk due to a higher calf to teat ratio increases competitive interactions and causes reduced milk intake (von Keyserlingk et al., 2004). In the current survey most farms allowed a ratio of either <5 kids or 6-10 kids per teat, however, 11-20 per teat was also widely used (Table 3-2). Feeding competition and the resulting impacts on welfare could be an issue within *ad libitum* milk supply systems and warrants further investigation.

3.5.3 Feeding management

Goat kid reticulo-rumen development is affected by the physical form of the diet (Hamada et al., 1976); therefore it is essential that young ruminants ingest solid feed and forage during the pre-weaning phase in order to develop a fully functioning rumen prior to weaning. In this survey forage was considered plant-based forages (such as hay and straw), whereas solid feed was compound/grain based (including both premade concentrates and home mixed straights). It was positive that most farms provided both at a young age (Table 3-3), as this enables the kids to become familiar with solid feeds before weaning and therefore develop a rumen capable of coping with the loss of milk-based nutrients. It is interesting to note that only a small number of farmers (22) provided access to pasture or browse, or fed 'tree hay' (1), as goats are naturally browsers/grazers (Goetsch et al., 2010) this would be the most ethologically appropriate source of forage and would encourage natural behaviours. The low number of farmers utilising this food source likely reflects challenges in collecting and storing this feedstuff.

Significant growth differences have been found between kids fed high and low protein diets (Greenwood, 1993), suggesting that adequate dietary protein intake is important for successful kid-rearing. This survey found high variability in type of solid feed offered but divided them into commercial complete feeds and home blends. The overall nutritional breakdown of a homemade blend is often unknown, and care should be taken to ensure a balanced diet that allows for good growth is achieved. Indeed, it has been found that feeding goat kids a pelleted complete feed alone compared to a combination of pellets and cereal grains increased weight gain (Hadjipanayiotou and Sanz, 1997). Goats are often considered a 'minority species and therefore access to goat-specific complete feed options is typically limited and other feedstuffs for small ruminants utilised (Table 3-3).

Solid feed intake has been positively correlated with reticulo-rumen weight (Hamada et al., 1976), and it has been found that kids consume more solid feed if milk is restricted rather than offered *ad libitum* (Economides, 1986). Therefore, the consumption of feed in *ad libitum* milk supply systems should be carefully considered, particularly around the weaning transition. Whilst solid feed is important for pre-weaning growth, feeding a diet high in concentrate solid feeds to goat kids during the growth phase can increase stereotypies and lead to impaired

welfare (Tölü et al., 2017), and therefore offering *ad libitum* forage is important. It was positive that the vast majority of farms provided forage; comparable to the 95.7% found by Anzuino et al. (2019). However, there is limited evidence to inform the optimum balance of forage and solid feed for rumen development during the milk feeding stage and further research in this area would be beneficial.

3.5.4 Weaning

Weaning (nutritionally; the process of transitioning from a milk-based diet to one composed of solid feedstuff) represents an important transitional phase of management. Whilst early weaning may be desirable in terms of management (including reducing labour and feed costs), timing weaning correctly is essential to animal welfare. There is increasing evidence from cattle that early high growth rates have long lasting impacts beyond the milk feeding and weaning period. Higher early growth rates result in higher bodyweight at 24 months of age, increased milk yields (Moallem et al., 2010), and reduces age at first calving (Raeth-Knight et al., 2009). Successful weaning (without significant morbidity and mortality) of goat kids has been documented at five weeks of age providing they were consuming at least 30 grams of solid feed daily pre-weaning (Lu and Potchoiba, 1988). The consumption of solid feed may be an important consideration in determining optimal weaning times, however, unlike in many calf operations, the technology able to monitor individual intakes is generally not used when rearing goat kids; therefore, weaning strategies tend to be based on easy to measure traits such as weight or age.

The current survey relied on farmer recollection of their weaning methods and therefore the results should be interpreted with some caution due to the limitations of recall-based methodology, however this study gives valuable insight into this under-documented area. The decision to wean based on age was the most common strategy found, with weaning based on a target body weight used less frequently (Table 3-4). This contrasts with dairy farms in New Zealand where most were using bodyweight as the criteria for weaning, however, only two of those farmers routinely weighed their kids (Todd et al., 2019). It was not investigated if farmers were weighing their kids prior to weaning or estimating weight visually which could be an important consideration for accuracy.

In Canada, Bélanger-Naud (2021) reported that most farms used a combination of age and weight as a weaning criterion, and the median target weight was 15kg (Bélanger-Naud, 2021), comparable to the Canadian median found in this study. In the UK 75.6% of dairy farmers used a target weaning age and 41.3% used a target weight (Anzuino et al. 2019), higher than found in the current study, perhaps due to the differences in purposes the kids are reared for. The current study found that target weaning ages and weights varied across

countries and as this may be influenced by breed and purpose it is important to note that the existing literature focuses on goats being raised for commercial dairy purposes, whereas the current study included all kids being reared artificially regardless of purpose. It has been suggested that weaning shock is more closely related to weight rather than kid age (reviewed by Lu and Potchoiba, 1988), however, it seems difficult to separate the two, and the evidence surrounding this is based on old data and limited sample sizes.

The process of weaning from artificial milk feeding systems can be conducted in two main ways, and this survey found that the weaning method chosen was related to the milk feeding system used. Abrupt weaning (the sudden and complete removal of milk) was more likely to be used by those feeding milk *ad libitum* whereas gradual weaning (the incremental reduction of milk before complete removal) was used more commonly by those bottle feeding. Calf research suggests that abrupt weaning results in lower growth rates than gradual weaning (Roth et al., 2009; Weary et al., 2008). However, there are minimal published studies specifically looking at method of weaning goat kids from artificial milk supply systems; (Zobel et al., 2019) and (Magistrelli et al., 2013) both found no significant effects of gradual weaning (by reduction in milk quantity or milk concentration) on weight or behaviour. In the current study over half of those using gradual weaning techniques began implementing these over a month before total milk removal, which likely has positive growth and welfare benefits as this extended timeframe reflects natural processes (Bungo et al. 1998 suggests kids begin to reduce suckling bouts from 35 days of age and Collias, 1956 that full weaning occurs between 84 and 168 days of age), however may be practically difficult in terms of kid management – particularly on larger farms.

In Canada, 37% of dairy farms were abruptly weaning, and methods of gradual weaning used were skipping milk feedings (20%), which is only possible from meal-based milk feeding systems, reducing milk quantity (19%), and diluting milk with water (10%) (Bélanger-Naud, 2020). In the current study, reducing milk quantity was favoured by the vast majority (Table 3-5) – a strategy difficult to implement in *ad libitum* milk systems and may explain why those systems were less likely to gradually wean. Of note from the current study's findings is that 29% of farms rearing the most kids per year (>600) were employing gradual weaning techniques and therefore investigation into how gradual weaning appears to be more feasible for very large farms warrants attention but is likely related to having dedicated kid rearing staff rather than more generalised farm workers who will have less time for kid rearing activities.

Calf research has documented that high milk intake results in decreased solid feed intake post abrupt weaning (Weary et al., 2008) and reduced weight gain linked to slower rumen development (Sweeney et al., 2010); suggesting that goat kids fed on *ad libitum* milk systems may have issues surrounding lower solid feed intake and slower rumen development that

impact them at weaning. As this survey found that kids fed on *ad libitum* milk systems are more likely to be abruptly weaned this could be a welfare concern, and the lack of species-specific weaning research should be addressed to fully understand how weaning strategies affect goat kid welfare. Weaning targets and management may have been influenced by breed and housing effects; investigation of these was not the primary objective of this study but inclusion of this in further studies could be warranted.

3.5.5 Environmental enrichment

It is widely accepted that commercial environments can restrict behavioural expression and environmental enrichment is often used with the aim of improving the welfare of captive animals (Newberry, 1995). Indeed, many farming industries use enrichment to these purposes. Species ethology is important when considering providing enrichment; wild goats generally inhabit complex topography consisting of steep mountainous terrain at high elevations (Parrini et al., 2003). Opportunities for goats to perform their full behavioural repertoire may be restricted by commercial housing, which generally allow little variation in elevation, surfaces and hiding opportunities.

This survey is the first to investigate the provision of enrichment to artificially reared goat kids, and it found that farmers had a variable understanding of what enrichment is, with some descriptions given not meeting the definition provided. Therefore, some may be providing items of enrichment but not recognising them as such, and the prevalence of enrichment use reported in our study could be an underestimate. Kids may also utilise structures that are part of the environment as unintentional enrichment such as stumps and trees in paddocks. However, for the purposes of this survey only specific items provided to the kids for the purposes of enrichment were acknowledged.

The most common type of enrichment provided were those classified as ‘occupational enrichment’ (Figure 3-3); including both physical and psychological/cognitive enrichment (Bloomsmith et al., 1991). Altering the physical environment by providing items that add complexity has been shown to increase feeding bout duration and decrease agonistic behaviour in adult goats (Aschwanden et al., 2009). Sensory enrichment (stimulation designed to trigger an animal’s senses; Bloomsmith et al., 1991) were mentioned in survey responses by a small number of farms (Figure 3-3). It has been found that in cows, music decreases stress levels (Kıyıcı et al., 2013), however it is unknown if the effect was due to changing human behaviour, and it has been noted that calves behavioural responses to brushes potentially indicate enjoyment (Westerath et al., 2014).

Social enrichment involves access to contact with other animals or humans (Bloomsmith et al., 1991), human contact was commonly regarded as enrichment; however, it is important to

note that not all contact is equal. In calves, positive early-life handling results in higher growth rates (Lürzel et al., 2015), and a more positive affective state (Ellingsen et al., 2014). However, negative interactions cause increased flight distances and reduced milk protein (Hemsworth et al., 2000). Social enrichment using other species is nuanced, for example canine interaction causes indicators of stress in sheep (Hansen et al., 2001) but evidence specifically related to interaction between goats and other species could not be found.

Nutritional enrichment involves presenting feed in a different way or offering novel feedstuff (Bloomsmith et al., 1991; Newberry, 1995) and can allow for increased expression of natural feeding behaviour. Raised feeding surfaces increase feed intake of adult dairy goats (Neave et al., 2018) and Zobel and Nawroth, (2020) suggest that feed presentation should be considered as a strategy to improve goat welfare. Nutritional enrichment made up a small percentage of the types of enrichment farms described, however those offering natural browse or allowing pasture access may also be unintentionally providing nutritional enrichment.

It was encouraging that this first investigation into the provision of enrichment to goat kids on-farm found that most provided some form of enrichment*,* however, there has been little peer-reviewed research into enrichment for goat kids and therefore evidence-based recommendations for species-specific enrichment are limited. There is a need for further investigation into appropriate enrichment for goat kids in order to ensure enrichment is fulfilling its essential aim of improving welfare.

3.6 Conclusion

Greater understanding of on-farm management can ensure research aimed at improving goat welfare is relevant and applicable to the various systems employed, and the scale and objectives of those systems. Whilst bottle feeding was the most common milk feeding method, followed by *ad libitum* systems, it was found that farms rearing >100 kids were significantly more likely to *ad libitum* milk feed. Kids were significantly more likely to be abruptly weaned from *ad libitum* milk feeding systems, or gradually weaned from bottle feeding. With evidence from other species suggesting that gradual weaning has welfare and production advantages over abrupt weaning, research on weaning strategies for *ad libitum* milk systems is needed. Enrichment was supplied on the vast majority of farms, with occupational enrichment being the most common type, but a greater understanding of the role of enrichment in improving the welfare of artificially reared kids, and how this interacts with other management practices is needed to help farmers make the right management decisions about use of enrichment. Overall, whilst consideration should be given to the representativeness of results from countries with a limited number of responses, this survey helps to build a knowledge base of on-farm management practices during the kid milk feeding stage and weaning transition, with the

variability in practice suggesting that applied research, tailored to the prevalent systems identified, is needed to inform best practice guidelines for rearing goat kids to ensure welfare is optimised. Several areas in need of further investigation have been highlighted.

3.7 Ethics approval

Ethical approval was granted by the University of Reading, School of Agriculture, Policy and Development (reference number 001095) and Dalhousie University (reference number 2019-4934).

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4. Rearing goat kids away from their dams 2: Understanding farmers' views on changing management practices

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It is estimated that the first author H M Vickery contributed approximately 85% of the work including conceptualization, producing and distributing the survey, analysing results and fully preparing the first draft. Authors R A Neal and R K Meagher provided supervision, assistance finalising the methodology and provided review and editing of the written paper draft.

4.1 Abstract

Improving animal welfare is an important aim of livestock industries and is dependent on human management. Understanding attitudes to change and perceived barriers is therefore a key consideration for welfare scientists. A survey that aimed to investigate farmers' attitudes towards changing goat kid rearing practices was distributed. Likert scales examined willingness to change and the importance of factors in decision-making alongside open text responses for further explanation. 242 farmers (United States of America (USA) 72; United Kingdom (UK) 71; Australia 33; Canada 23; New Zealand 20; European Union 14; Other 9) rearing goat kids away from their dams responded. All respondents rated from one (highly unwilling) to seven (highly willing), how willing they would be to supply three enrichment types. Willingness to provide enrichments differed ($\chi2(2) = 190.114$, $p<0.001$), with farmers most likely to provide climbing or loose items rather than swinging items. The most common reasons cited for unwillingness to provide enrichment were related to safety (101 responses / 76.5%). Those currently abruptly weaning were asked how willing they would be to use gradual weaning methods. Those abruptly weaning from ad libitum milk systems (n=47), showed no difference in willingness to change to different gradual weaning methods; median (IQR) willingness to change to removing teats was 2 (1 – 4), reducing milk temperature 3 (1 – 5) and diluting milk 2 (1 – 5), with most concerns relating to feasibility. Those abruptly weaning from bottle feeding (n=18) also showed no difference in willingness to change to gradual weaning methods. Median (IQR) score for willingness to change to reduced number of bottle feeds was 4 (1 – 7), reducing milk quantity 3 (1 – 6.25), and diluting milk 1 (1 – 5), respectively. Health concerns were the most common reason for not being willing to change. All 242 respondents were asked to rate how important different factors are when deciding to implement a new management practice. There was a significant difference in importance between factors ($\chi2(2) = 34.779$, $p<0.001$). Median (IQR) importance of the factors was: labour/time 5 (4 – 7), cost 5 (4 – 7), evidence beneficial to welfare 6 (5 – 7), evidence beneficial to health 6 (5 – 7), and evidence beneficial to growth 6 (4 – 7). To our knowledge this is the first study to examine goat farmers' attitudes towards changing management practices and could help ensure that future research addresses farmer concerns and therefore has the best opportunity to be implemented on-farm.

4.2 Introduction

Whilst the improvement of animal welfare involves many stakeholders within the agricultural and food industries, farmers, as the caregivers responsible for day-to-day husbandry of animals, have a large influence over animal welfare, health, and productivity (Boivin et al., 2003; Hemsworth, 2003). Implementing change relies on best-practice research being adopted on-farm, and whilst farmers perceive actions to improve welfare as important, they often find them difficult to implement (Kauppinen et al., 2010). Therefore, to have the largest impact, it is essential that research is targeted and feasible for application. As farmers implement husbandry and management practices daily, understanding their willingness to change current management and their reasoning could help ensure this.

Consumer concern is often directed toward separating young animals from their dams and the subsequent artificial rearing period (Hötzel et al., 2017); a common practice in the dairy goat industry (Anzuino et al., 2019). Kids can be reared artificially in other systems for multiple reasons, including low milk yield caused by mastitis, dam rejection, and litter size greater than two. The milk feeding stage and weaning transition are a high-risk period for young ruminants (Todd et al., 2019), yet despite the global popularity of goats, there is little information about the systems used to rear goat kids away from their dams.

The early-life environment is particularly important to future development, evidence suggests that animals reared in constant, non-demanding environments can later show reduced behavioural flexibility (Price, 1999), whereas providing species-appropriate enrichment can promote behavioural flexibility (Clemenson et al., 2015). As many goat kid rearing environments can be constant and barren for reasons of hygiene and practicality, providing species-appropriate enrichment seems an important consideration. Zobel and Nawroth, (2020) suggest that enriched environments resulting in increased behavioural flexibility could help individuals better cope with management-related stressors. This appears relevant during the weaning transition when kids are expected to cope with large changes to their feeding regimes, often alongside changes to their social and physical environment.

Under natural conditions, goat kids are weaned from milk between 84 and 168 days of age (Collias, 1956). However, in commercial situations they are weaned from milk younger (20/29 farmers aiming for 42 to 56 days of age in the United Kingdom (UK); Anzuino et al., 2019) and over a reduced timeframe without dam cues that cause a gradual reduction in milk intake alongside increased solid feed intake. This weaning transition is a stressful experience for goat kids, evidenced by reduced growth rates (Newberry and Swanson, 2008) and development of oral stereotypies (Atasoglu et al., 2008). Many calf studies evidence how gradual weaning (the stepwise removal of milk) has benefits over abrupt weaning (the sudden and complete removal of milk) including earlier solid feed intake (Scoley et al., 2019), higher

growth rates (Weary et al., 2008), and increased gastrointestinal tract adaptation (Steele et al., 2017). Whilst gradual weaning research is extensive for calves, this literature focuses on individualised methods that rely on technology (such as computerised feeders that step-down individual milk allowance) not currently utilised on goat farms, and therefore currently has limited applicability. The gradual weaning strategies proposed within this survey were designed to be possible in low-tech systems.

This paper presents information collected by the second part of a survey, where the first part detailed existing management practices used to rear goat kids away from their dams (Vickery et al., 2022). This survey was designed to obtain open-text discussion of Likert-scale answers so a greater degree of detail on farmers' opinions could be collected to enable an informed approach to future research. The overall aim was to investigate farmers' attitudes towards changing their current kid-rearing practices, in order to identify common reasons underlying their views and ascertain the importance of factors to the uptake of new strategies and what barriers may prevent this.

4.3 Material and methods

4.3.1 Questionnaire

A two-section anonymous questionnaire was designed. The first section collected information on farm characteristics and current management practices which are presented in Vickery et al., (2022). The second section is the focus of this paper and investigated farmers' attitudes towards changing management practices. Seven-point Likert scales asked farmers to indicate their willingness to change to new weaning methods, provide environmental enrichment, and the importance of various factors to their decisions to implement new strategies (Appendix 1). Optional open-text responses allowed farmers the opportunity to elaborate on their score.

The entire two-section survey was designed to be completed from memory within ten minutes; routing directed respondents to sections specific to their current management practices. For example, the Likert-scale questions on changing to gradual weaning strategies were only answered by those currently abruptly weaning, and respondents were directed to separate questions; one for those using ad libitum milk feeding systems and one for those bottle-feeding. After piloting the survey on five farmers, minor changes were made to question format. Dutch and French translations were created and checked for accuracy by back translation and discussion with native speakers.

4.3.2 Participation criteria and recruitment

To participate respondents had to be raising goat kids away from their dams and only submit one response per farm. Due to the primary researcher being based in the UK, paper copies were distributed at the Milking Goat Association open day (September 2019), Goat Veterinary Society conference (October 2019), and the Dairy, Sheep and Goat Conference (January 2020). Further in-person distribution was not possible during the remaining recruitment period due to Covid-19. An electronic version (translations available in French and Dutch) was distributed via the researchers' social media accounts and emailed to relevant organisations (including the International Goat Association, regional goat societies and veterinary services) for further distribution from September 2019 to June 2020. No promotions were paid for, and no incentive (financial or otherwise) was offered to participants.

The survey expected to receive the highest proportion from the UK and the United States of America (USA) as these areas are predominantly English speaking and have a greater level of organisation into associations/groups, and the researchers' social networks were based predominantly in the UK and North America, which could have impacted responses received. However, the survey welcomed a wide range of participants from geographical areas with commercial farms in order to identify common themes across goat-keepers. The translations were created to assist in receiving more responses across North America and Europe.

4.3.3 Thematic analysis

All responses were collated and coded in Microsoft Excel. Thematic qualitative analysis of open text responses (Braun and Clarke, 2006) was used to group the responses based on their content in order to identify patterns of meaning. If a response fit into more than one theme it was counted within both categories. The number of comments within each theme were presented to allow for quantitative comparisons of the frequency of that opinion. Direct quotes presented were lightly edited for spelling and grammar.

4.3.4 Statistical analysis

Statistical analysis was conducted in IBM SPSS (version 25; SPSS Inc., Chicago, IL, USA). Most results are presented as simple summary statistics. The Friedman test procedure was used to look for significant differences between the options in each of the four Likert-scale questions. Post hoc analysis with Wilcoxon signed-rank tests with a Bonferroni correction applied was then used to examine where differences occurred.

4.4 Results

4.4.1 Survey exclusions and response

Three paper and five online responses were excluded due to incomplete responses, dam reared kids, or incorrect species. After removals, 14 paper copies were used, 212 responses from 16 countries were collected from the English online version, the Dutch translation received one response (from The Netherlands), and the French version gained 15 responses (eight from France, seven from Canada), giving an overall total of 242 surveys included in the analysis. These responses were from the USA (72), UK (71), Australia (33), Canada (23), New Zealand (20), the European Union (14), and 'Other countries' (9) which included South Africa (2), Thailand, Nigeria, Indonesia, Guatemala, Iran, Jamaica and Portugal. Farms rearing less than 100 kids per year were overrepresented - making up 74% of the responses (180/242 farms). Further detail regarding system characteristics can be found in (Vickery et al., 2022).

4.4.2 Changing management practices – gradual weaning

Gradual weaning from ad libitum systems

All respondents were asked how willing they would be to change to three different gradual weaning methods, one respondent answered the wrong section and was therefore excluded, giving a total of 47 responses. There was no significant difference in willingness to change to different proposed gradual weaning methods (Table 4-1). Where respondents were given the opportunity to explain their rating in open text, seven felt that their abrupt weaning system worked well and therefore did not feel the need to change. Nine responses mentioned that changes at a machine level were not possible as one machine fed multiple pens of kids of different ages that would not be ready to wean at the same time, such as: "We have different age range of kids on the milk machine. It wouldn't be possible to reduce temperature or decrease milk powder without affecting younger kids" (Respondent 1).

Table 4-1. Results from Friedman tests of Likert-scale (1- highly unwilling, 4 – neither willing or unwilling, 7 – highly willing) responses to questions with post hoc Wilcoxon signed-rank tests of how willing farmers are to change management practices of goat kids reared artificially.

	Likert-scale							Median (IQR[1])	χ^2	P
	1	2	3	4	5	6	7			
How willing would you be to change to the following gradual weaning methods from an ad libitum milk feeder (n=48)?										
Decrease the ratio of milk powder to water	20	5	2	4	8	4	4	2 (1-5)		
Reduce milk temperature to cold	18	5	2	8	4	2	8	3 (1-5)	2.687	0.261
Remove *ad lib*. teats for a set period of hours per day	19	6	4	11	4	2	1	2 (1-4)		
How willing would you be to change to the following gradual weaning methods from bottle feeding (n=18)?										
Decrease the ratio of milk powder to water	11	1	0	1	2	0	3	1 (1-5)		
Reduce the quantity of milk in each feed	7	1	3	2	0	1	4	3 (1-6.25)	5.515	0.630
Reduce the number of bottle feeds per day	5	2	1	2	2	1	5	4 (1-7)		
How willing would you be to supply the following enrichment items (n=242)?										
Loose items in the pen	23	16	8	37	31	16	111	6[a] (4-7)		
Swinging items	106	12	12	32	16	14	50	3[b] (1-6)	190.114	<0.001
An object that allows the kids to climb on top of it	21	6	5	14	13	14	169	7[c] (6-7)		

[1] IQR = Interquartile Range
[a,b,c,d] Median values with different superscripts differ significantly at $P<0.01$

Feasibility concerns were mentioned by eight, including ability to get staff to change routine, time needed, and machine limitations (such as an inability to change milk temperature and powder ratios). Health concerns were mentioned by seven; of those, five were concerned that milk teat removal would cause issues related to gorging and competition once milk access was returned. For example, they stated, “When kids are deprived of milk for a certain period, they force-feed themselves afterwards and bloat problems appear” (Respondent 2).

Concerns about scouring and weight loss with a powder ratio change were mentioned by two; “Watering it down results in malnourishment and bloating - the kids cannot get the nutrition they require… and just keep on drinking. This leads to bloat and death” (Respondent 3), and one fed whole milk so was unable to change powder ratios.

Gradual weaning from bottle feeding

All respondents currently abruptly weaning from bottle feeding were asked to rate how willing they would be to change to different gradual weaning methods, one respondent answered the wrong section and was therefore excluded, leaving a total of 18 responses. There was no significant difference in willingness to change to different gradual weaning methods (Table 4-1). Respondents were given the opportunity to explain their rating, and common themes were identified. Health related reasons were stated by four including that “abrupt weaning gives less chance of bloat” (Respondent 4), and the other three specifically mentioned milk dilution; “I would never decrease the ratio of milk powder to water because feeding a kid too much water from a bottle can cause death. I'd only reduce the ratio in a young kid who has stomach upset from powder overload. Never in a healthy kid” (Respondent 5). Six respondents felt their current abrupt weaning system worked well and expressed not seeing any reason to change such as: “It is simply delaying the inevitable and prolonging stress” (Respondent 6).

4.4.3 Environmental enrichment

All 242 respondents were asked to rate how willing they would be to supply different types of enrichment, there was a difference in willingness to provide enrichment depending on the type (Table 4-1). Respondents were given the opportunity to explain their score, 132 open text responses were collected and thematically analysed (Table 4-2); safety was the main concern, particularly around hanging objects.

Table 4-2. Thematic analysis of 132 comments received in response to asking participants why they were unwilling to provide enrichment to artificially reared goat kids.

Theme of free-text comments	n (%) for theme	Example quotes from theme
Safety	101 (76.5)[1]	"*Why let them hang themselves after all the bluddy hard work or having to set limbs cos they broke a leg in the hay net*" (Respondent 12 "*I consider hay nets extremely high risk for goats, and even a hanging ball etc has the potential for the rope/chain it is hanging from to wrap around a kid's neck and strangle it."* (Respondent 13) *"Our goats make a determined effort to find inventive ways to kill or injure themselves…. Adding new ways for them to injure themselves/destroy more fencing and feeders etc isn't very appealing"* (Respondent 14) "*Baby goats and a net makes me think of legs caught in the net- been there, done that, got the $450 vet bill to prove it*" (Respondent 15)
Feasibility	9 (6.8)	"*Bulk object complicates litter management*" (Respondent 2) *"I don't have the ability to safely install a hanging item*" (Respondent 16)
Provided before but not used	9 (6.8)	*"I've tried the ball and hanging ball idea and it never really did anything for them"* (Respondent 17) *"We have previously put a loose ball in the pen for the kids to play with and they took no interest"* (Respondent 1)
Future behavioural issues	6 (2.5)	*"Hanging items teach a goat to rear and jump - which can make it difficult to manage the behaviour of that animal in the future"* (Respondent 7) *"Swinging items encourage head butting random things including yourself. Table being so high can encourage jumping fences"* (Respondent 18) *"Experience has shown me that with play structures, they develop reflexes to jump outside the pens"* (Respondent 19)
Hygiene	5 (2.1)	*"It can be very difficult to thoroughly clean/sanitize these items, therefore increasing disease in our pens"* (Respondent 20)
Not necessary	2 (0.8)	"*Not necessary*" (Respondent 21)

[1] Of these responses 53 specifically mentioned that hanging nets are of high safety concern.

4.4.4 Barriers to uptake

All 242 respondents rated how important different factors were to them when deciding whether to implement a new management practice, and there were significant differences between the importance of different factors (Table 4-3). Respondents were given the option to

make further comments on barriers to uptake of new practices; 16 chose to write a response. Issues related to feasibility and practicality were stated by four, “Farmers are practical. They have to be. If changing a practice has benefit in the long run and has some backing to it, most will entertain the thought. But whatever the suggestion is, it must be practical” (Respondent 7). Economic considerations were mentioned by a further four, “Inputs need to be justified by output…. a lot of the scientific reports on welfare are unquantifiable so not relevant” (Respondent 8), and “The cost of milk replacer continues to rise…. I feel I have to compromise because of cost” (Respondent 9). Four respondents felt that a lack of research is a barrier; “We will implement anything that benefits the kids – but we don’t have much info on what to change!” (Respondent 10). Three responses stated that they preferred anecdotal/trial and error experience over scientific research; and “Performance is key, tend to rely on experience rather than scientific evidence” (Respondent 11). Additionally, one response explained how Johne’s disease control impacted their ability to change management.

Table 4-3. Results from Friedman tests of a Likert-scale (1- highly unimportant, 4 – neither unimportant or important, 7 – highly important) question with post hoc Wilcoxon signed-rank tests of how important factors are to farmers rearing goat kids artificially when deciding whether to implement a new management practice (n=242).

	Likert-scale							Median (IQR[1])	χ^2	P
	1	2	3	4	5	6	7			
Evidence that it will benefit growth rates	14	7	10	30	30	52	99	6[a] (4-7)	34.779	<0.001
Evidence that it will benefit health	15	5	10	19	25	57	111	6[b] (5-7)		
Evidence that it will benefit welfare	14	8	10	21	38	56	95	6[ac] (5-7)		
Cost required	15	10	10	36	61	38	72	5[d] (4-7)		
Labour & time required	23	14	6	39	49	35	76	5[ad] (4-7)		

[1] IQR = Interquartile Range
[a,b,c,d] Median values with different superscripts differ significantly at $P<0.01$

4.5 Discussion

This is the first study to use qualitative techniques to attempt to understand goat farmers’ perspectives on changing management, providing valuable insight but with the recognised limitations of an anonymous recall-based survey approach. The survey received more responses from certain geographical areas. This is likely in part due to these regions being predominantly English-speaking, thus able to complete the English survey and more likely to be reached by the researchers’ social networks; they may also have greater organisation into

groups/ associations that enabled more efficient survey distribution. Responses were skewed towards greater representation of smaller farms and likely represent a diverse range of management practices, as explored in the first part of this survey (Vickery et al., 2022). Despite diversity in both geography and husbandry, common themes were identified, suggesting that they prevail across a heterogeneous sample and are likely to be relevant to a wide range of goat keepers. However, it is acknowledged the responses received may not be typical of all goat keepers, and those willing to participate in a voluntary survey could have biased views. Some farmers chose not to leave detailed open-text responses, likely due to time pressures which is why the survey questions were kept to key, structured themes and did not investigate in-depth socio-demographic data; we recognise that alternative tools such as in-depth interviews would have enabled deeper investigation and coverage of more factors influencing practice, but may not have reached the same breadth of farmers. Whilst both broader and deeper methods of exploring farmers' views would enable greater understanding of influencing factors such as farm type, productivity drivers and sociodemographic variables, the Likert responses and open-text comments collected in our study provide a useful starting point in this novel area and are explored throughout the rest of this discussion.

4.5.1 Gradual weaning

Weaning animals from artificial milk supply systems is stressful and can cause reduced growth (Newberry and Swanson, 2008), increased vocalisations (Budzynska and Weary, 2008) and the development of stereotypies (Atasoglu et al., 2008). Calf studies indicate that gradual weaning can mitigate these detrimental impacts (Scoley et al., 2019; Weary et al., 2008), yet within the goat industry, large farms (>100 kids) feeding milk ad libitum are most likely to wean abruptly (Vickery et al., 2022) possibly due to a lack of feasible group-level gradual weaning methods. Indeed, our survey found that those currently abruptly weaning from ad libitum systems had concerns relating to feasibility, particularly around the ability to wean on a pen-level. Concerns were expressed that ad libitum milk feeding machines with limited technical capabilities (beyond mixing milk and maintaining temperature) feed multiple pens of kids of different ages. Therefore, machine level changes, such as reduction in milk temperature or dilution, would affect all kids being fed - when they may not be ready for weaning over the same timeframe. We propose that for recommendations to be feasible for use on goat farms feeding milk ad libitum, they should be targeted at pen-level strategies.

Other strategies to attenuate post-weaning stress could include the use of social facilitation with the addition of older animals and positive human contact (higher weight gains and lower cortisol in lambs; Pascual-Alonso et al., 2015; reducing abnormal behaviours, cortisol and encouraging positive social behaviours in foals; Henry et al., 2012). This survey considered

only physical methods of weaning from milk that are relevant to many production systems, however future research could consider social strategies and the feasibility of implementing them.

There was consistent unwillingness among those surveyed to adopt all three proposed gradual weaning strategies, but respondents explained concerns specific to removing ad libitum teats, and how this could cause gorging and subsequent bloat when milk access is reinstated, as well as injuries related to increased competitive interactions due to the provision of one teat to multiple kids. No literature could be found to address these concerns and therefore understanding feeding competition and milk intake relating to removing and replacing ad libitum milk access needs investigation. Similar views were expressed by those who bottle feed, including the statement that abrupt weaning gives less chance of bloat; a common concern expressed in personal communication with farmers, yet no literature can be found to support this belief. This highlights the importance of understanding why farmers are concerned about potential strategies, to be able to perform research which clearly addresses these and improves the likelihood of adoption of new practices. Perceived negative impact on animal health appears to be a major barrier to adoption and is therefore high priority for future work.

4.5.2 Environmental enrichment

Environmental enrichment is widely used with the aim of improving captive animal welfare (Newberry, 1995), and there is copious evidence from other species that enrichment improves welfare (farm animal review: Bolt and George, 2019). Effective enrichment must be biologically appropriate (Newberry, 1995) and should consider the species' natural ethology. Wild goats inhabit terrains of varying elevations (Parrini et al., 2003), and are both browsers and grazers (Goetsch et al., 2010), that spend time browsing bipedally (Sanon et al., 2007), therefore providing enrichment that enables goat kids to exhibit a behavioural repertoire including climbing, hiding, and browsing within captive conditions could improve welfare. To choose effective enrichment provisions, preference tests can help to identify species-specific characteristics of preferred items (Mench, 1998); whilst these have limitations, they can form a useful basis for decisions, yet none have been conducted for goats. Caution should be taken to ensure items are not chosen anthropomorphically which can result in ineffective provisions and could be the reason for comments saying kids had not used enrichment, indeed Van de Weerd et al., (2003) advise using behavioural observations to identify efficacious enrichment and ensure choosing on an intuitive basis is avoided. Further research to identify valuable enrichment for goat kids would be useful; whilst Rosas-Trigueros et al., (2017) found that kids enriched with sacks of henequen, trunks, tyres and coconuts had lower stress levels and

recommended the use of environmental enrichment, the items were not assessed individually, and it is unclear which were most valued.

Even when enrichment has been validated, habituation remains a challenge around its long-term effectiveness (reviewed by Tarou and Bashaw, 2007), particularly for simple inanimate objects, which are often the most feasible addition and the focus of our survey. Habituation may be age-related, and whilst age difference effects have been scarcely studied in farm animals they have been observed in pandas (Swaisgood et al. 2001) and chimpanzees (Lambeth and Bloomsmith, 1992). There may be greater intrinsic reinforcement for play in juveniles (Fagen, 1981) which could explain differences in enrichment effectiveness between age groups, with young animals habituating more slowly. Communication to farmers around rotating enrichment items could combat habituation (evidenced in other species; Renner et al., 2000), and strategies to ensure enrichment is engaging long-term should be an important consideration for future research.

Zobel and Nawroth, (2020) suggest that food provision enrichments could be biologically relevant, and in adult goats raised feeding surfaces increase intakes and appear to be valued (as inferred by it increasing the frequency of competitive interactions; Neave et al., 2018). Therefore, an example given in the survey for 'swinging items' was haynets – a common provision for many animals. This prompted a significant number of strong responses (Table 4-1) regarding concerns over safety. Zobel and Nawroth, (2020) suggest that farmers' concerns could stem from goats lacking early life experience (particularly with climbing structures) leading to problems when they are introduced and suggest that providing early-life enrichment is instrumental to goats being able to safely utilise enrichment later. Safety concerns may be addressed by allowing access to simple structures from a young age to increase spatial awareness and ability to safely navigate structures, and this needs to be communicated to farmers. It is essential that any enrichment suggested has been trialled and monitored for effectiveness and safety, in order to be able to effectively alleviate farmer concerns and therefore reduce a barrier to providing it. Some respondents expressed concern regarding enrichment encouraging future behavioural issues, such as head-butting and escaping from enclosures, a concern noted by Zobel and Nawroth, (2020) who suggest that providing increased environmental complexity and variability would reduce boredom (a welfare concern; Meagher, 2019), and dissuade mischievous behaviour. Whilst no research has investigated this, Miranda-de-la-Lama et al., (2013) found that adult goats in enriched environments stayed on average one metre further away from humans which could be of concern to farmers. However, the same study also found that unenriched animals took longer to be caught, so the implications are unclear.

With little peer-reviewed research investigating enrichment for goat kids during the milk-feeding period there is limited evidence with which to persuade caregivers of the benefits enrichment can provide. As enrichment is beneficial to many farm animal species (reviewed by Bolt and George, 2019), and in limited goat kid studies has been evidenced as providing growth benefits (Flint and Murray, 2001), increasing behavioural repertoires (Tolu et al., 2017), and reducing stress (Rosas-Trigueros et al. (2017), there is a need for further research to identify suitable enrichment items. Whilst enrichment provisions could include the addition of older or suckler animals, for the purposes of this survey the focus was on inert strategies that could be easily utilised within many systems. Research aiming to investigate specific provisions for goat kids in order to recommend safe and efficacious species-specific enrichment that improves overall welfare would be warranted. However even in species where extensive research evidencing benefits exists, poor industry implementation remains (pigs; Van de Weerd and Ison, 2019) so improved communication with farmers remains an essential consideration.

4.5.3 Barriers to uptake

It has been proposed that whilst farmers see animal welfare as important, they struggle to implement changes to improve it (Kauppinen et al., 2010), a finding supported by this survey. It has also been suggested that farmers link ‘welfare’ to issues of basic husbandry (physical health, access to food and water) and factors important to optimising production (Te Velde et al., 2002). Anzuino et al. (2019) highlighted that farmers felt that kid health research was of key importance, a finding supported by our results, but farmers may need training on broader animal welfare concepts, in order to accurately give their perceptions.

In our study some farmers expressed that they saw no need to use gradual weaning as their methods seemed to work, similar to Te Velde et al., (2002) who reported that farmers consistently believed that their livestock had no welfare issues. Research shows that if farmers cannot be convinced that there will be tangible benefits then changes are unlikely to occur (reviewed by Rose et al., 2018). This evidence illustrates the need for research to demonstrate potential for improvements. For example, Sumner et al. (2018) concluded that providing dairy cow farmers with access to data that could be used to judge their success (benchmarking) could promote and inform management changes.

It was suggested in a Department for Environment, Food and Rural Affairs (DEFRA) commissioned review (UK) that farmers should be involved (participatory engagement) in planning research to ensure that resulting findings are feasible and have the greatest potential of adoption (Rose et al., 2018). We agree and believe it would be advisable that future research considers farmers’ perspectives beforehand, and that findings quantify a range of possible incentives including kid health, cost and labour analyses. Yet even when research is available,

many farmers feel that academic research does not reflect real world conditions and is therefore not applicable to them (Alarcon et al., 2014), and whilst early-stage participatory engagement could help mitigate this there are also farmers who stated a preference for anecdotal evidence. Wood et al. (2014) found that farmers value knowledge that is practice-based and that their learning often comes from personalised, local exchanges. A review by Blackstock et al. (2010) suggested that for farmers to consider a change they must be persuaded that there is a problem, and that their actions could solve it – highlighting the importance of communicating research to farmers in order to address these steps and create on-farm change.

Underlying perceptions that impact farmers' behaviours are often overlooked when considering how management practices are utilised (Blackstock et al., 2010) and our study is the first to attempt to address this for goat kids. Our findings suggest that farmers are particularly concerned about kid health and survival, given several responses focused on avoidance of bloat, and the safety of enrichment items, however practical considerations are crucial to feasibility. Overall, we suggest that more evidence is needed to guide farmers' management decisions, and research should aim to provide clear, practical information that enables them to make well informed decisions about animal management. However, a low number of respondents provided open text responses regarding barriers to uptake, possibly due to survey fatigue as it was the last survey question, so these responses must be considered cautiously as they may not be reflective of all goat farmers.

Results from Rehman et al. (2007) reinforce the importance of attitudes in the successful adoption of new technology and showed how knowledge transfer needs to consider opinions of potential adopters. In-person qualitative interviews may be beneficial to further uncovering farmer's attitudes toward management changes and could be used to identify links with sociodemographic and farm characteristics, however this carries a greater risk of biasing answers, whereas the anonymity of this online survey should have resulted in honesty. Whilst information sources are crucial to uptake of good practices farmers often have difficulty accessing and understanding scientific findings (Alarcon et al., 2014), therefore, to improve goat kid welfare, successful dissemination of knowledge must be considered and planned. This could include open-access research articles and involvement of influential stakeholders such as vets and agricultural extension/farmer education experts, as demonstrated by Atkinson et al., (2017) who found that involving producers and veterinarians in a benchmarking programme improved calf welfare outcomes. The results of this survey (highlighting areas important to farmers when deciding whether to implement a change) should be considered when research into goat kid management is being planned.

4.6 Conclusion

This novel survey highlights a need for more research in key areas that aim to address the identified common concerns of farmers raising goat kids, and ultimately provide improved communication with farmers, in order to progress towards improved goat kid welfare. Kid safety and health were concerns shared by many respondents with regards to environmental enrichment, and gradual weaning strategies and should be a priority for future research. Farmers need further information on enrichment in order to be persuaded that safe enrichment with clear benefits can be provided to young goat kids. Feasibility was a common theme found in farmers' responses across all parts of the survey; concerns over not implementing gradual weaning related to being able to apply the strategy. Therefore, it is recommended that feasibility be considered when planning research and that economic considerations should be included as an output of future projects, in order to provide findings that have the greatest chance of being utilised. This examination of goat farmers' attitudes towards changing kid-rearing management practices can help target future research based on farmer concerns and therefore increase the likelihood it will be implemented on-farm. Whilst further research with methodologies which enable in-depth analysis of farmer attitudes and consider more sociodemographic, production and farm size factors would be beneficial, this study provides a key initial insight.

4.7 Ethics approval

Ethical approval was granted by the University of Reading, School of Agriculture, Policy and Development (reference number 001095) and Dalhousie University (reference number 2019-4934).

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5. A preliminary investigation of the feeding behaviour of dairy goat kids reared away from their dams on a computerised ad libitum milk feeding system

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It is estimated that the first author H M Vickery contributed approximately 75% of the work including conceptualization, methodology, data collection, analysing results and fully preparing the first draft. Authors R K Meagher, S Stergiadis and R A Neal provided supervision, assistance with finalising methodology and provided review and editing of the written paper draft. Additional contribution was made by Dr Phil Assheton who provided the specialist statistical advice for the Gaussian-based meal analysis.

5.1 Abstract

Most commercial dairy goat famers use ad libitum milk feeding set-ups that allow constant, unrestricted milk access to artificially rear goat kids. No detailed information on how kids use these ad libitum milk systems exists and characterising this would help target future research and improve management. The aim was to describe and characterise the individual and group milk feeding behaviour of 16 castrated male dairy breed goat kids from 22 to 56 days of age, in two pens fed from a computerised milk feeder supplying one teat per pen. Solid feed and water intakes were measured from 15 to 70 days of age and Average Daily Gain (ADG) calculated. Repeated measures mixed models produced weekly estimated marginal means of milk feeding variables. Factors influencing ADG were investigated using residual maximum likelihood analysis. Spearman's rank correlations investigated the relationship between pen-level feeding behaviour variables and age. Meal criterions were created by fitting a mixture of Gaussians to determine a threshold value. On average it took 7.8 days before kids were reliably suckling alone (range 2-15 days). Each day kids spent on average 24.3±1.80 min feeding and consumed 1968±99.6 ml of milk. Mean individual daily milk consumption increased with age (p <0.001; 1623 ml/day week four to 2222 ml/day week 8), as did milk intake per meal (p <0.001). The number of daily rewarded milk station visits averaged 8.4±0.14 (range 2 – 19). Daily milk meals and time spent milk feeding was not impacted by age (p 0.666; p 0.095). ADG was not associated with age (p 0.226; weekly average 0.19 – 0.22) and was most impacted by an interaction between daily milk intake and week (p <0.001). All solid feed and water intakes were positively correlated with age during the milk-feeding period (p <0.001) and increased steeply when weaning occurred at the industry average of 56 days old. Each kid consumed 5.9±0.28 meals per day (1.4±0.9 visits to the teat per meal), which lasted 4.1±0.22 min and resulted in a consumption of 342.8±20.7 ml per meal. There was little evidence of close consecutive feeding, 57% within the 'social' meal Gaussian-defined time criteria were individual feeds, only 21% consisted of two kids, 10% three and 12% four or more kids, however, 74% of milk intake occurred during meals with >2 kids. This study showed that a computerised milk feeder can provide data on goat kid feeding which can be used as a baseline for future research.

5.2 Introduction

In the dairy goat industry it is widespread practice to remove kids from dams and rear them using artificial milk feeding systems (Anzuino et al., 2019; Belanger-Naud et al., 2021; Hempstead et al., 2021), whilst the length of time kids spend with their dams varies, removing immediately after birth is common practice (21.7% of farmers UK, Anzuino et al., 2010; 65% Canada, Bélanger-Naud et al., 2021; 76% USA, Hempstead et al., 2021). Optimising survival and growth during this stage is essential for raising quality replacement animals to ensure future productivity (reviewed for cows by Palczynski et al., 2022). Feeding a fixed number of restricted quantity meals per day or allowing unrestricted access to milk through an automated feeding machine is common, and the likelihood of the latter (ad libitum milk feeding) increases with number of kids reared (Vickery et al., 2022).

Automated ad libitum systems are the most common system used in commercial dairy goat rearing (UK, Anzuino et al., 2019; Canada, Bélanger-Naud et al., 2021; USA, Hempstead et al., 2021), as they represent lower labour inputs than meal-based systems that feed fixed, and limited quantities of milk at set times. In calves, higher milk intakes from ad libitum systems have been evidenced as having advantages over restricted milk feeding, including increased milk intakes (Appleby et al., 2001; Hammon et al., 2002), improved weight gains (Jasper and Weary, 2002), and allowing the expression of natural suckling behaviours (Hammell et al., 1988). In ad libitum systems for goats, milk is typically fed through teats attached via tubes to an automated milk machine (Vickery et al., 2022). However, these systems do not utilise the individualised technology increasingly common in calf systems (Rutten et al., 2013), that allows for the computerised monitoring of individual milk intake. Due to the low economic worth of individual goat kids compared to calves, and high investment required for this technology, they have not yet been adapted for use on goat farms. Therefore, no literature has reported how kids use these ad libitum milk teats and the amount of milk consumed before weaning.

Initially goat kids rely on milk, but they begin to consume solid feedstuffs within the first few weeks (Nicol and Sharafeldin, 1975). Whilst benefits of ad libitum milk systems have been described (Appleby et al., 2001; Jasper and Weary, 2002), lower solid feed intake and slower rumen development may be an issue, particularly during abrupt weaning (Jasper and Weary, 2002; Khan et al., 2007). Although there is extensive research on calf feeding behaviour, limited information is available for goat kids (last reviewed by Lu and Potchoiba, 1988). Increasing our knowledge of the development of both milk and solid feedstuff feeding behaviour under commercial artificial rearing conditions could have implications for management and welfare, particularly around understanding goat kid individuality and improving animal welfare and performance during weaning transition.

This study is the first to present an analysis of feeding behaviour of dairy goat kids reared away from their dams on an ad libitum milk feeding system, using individualised calf feeder technology to monitor individual goat kid milk feeding behaviour, alongside assessments of weight gain, video observations, and pen-level solid feed and water intake. The aims of the present study were: (1) to describe the individual milk feeding behaviour of goat kids reared with ad libitum milk access, (2) to quantify solid feed and water intakes and identify the effect of weaning on them, (3) to identify the relative importance of milk feeding variables (quantity of milk consumed, time spent feeding, number of meals) to Average Daily Gain (ADG), (4) to identify a meal criterion (by fitting a mixture of Gaussians to determine a threshold value) for individual and social milk feeding behaviour. The information presented has implications for farmers and researchers and can help to form the basis for future goat kid work during the milk-feeding stage and weaning transition.

5.3 Material and methods

5.3.1 Animals, housing and feeding

From June to September 2021 mixed dairy crossbred (Alpine, Toggenburg and Saneen) male kids were collected in two groups (one group for each pen) from a single private farm at three to seven days of age and taken to the rearing facility (Somerset, England) comprising of standard livestock barn housing with enclosed sides. The kids (who had been grouped upon separation from their dams at the private farm) were allocated to two pens and twelve and eleven kids per pen were initially allocated. Due to an outbreak of rotavirus upon arrival, any kids showing signs of ill health or reluctance to feed were removed before the study began (within four days of arrival). As a result, Pen 1 housed eight kids (one died of pneumonia at 20 days of age leaving seven kids in pen 1), and pen 2 housed nine kids for the duration of the study.

Kids were cared for according to standard commercial practice, castrated via elastration at <7 days of age, bedded on straw and received Heptavac P+ vaccinations at three and seven weeks of age. Kids had access to ad libitum creep feed (Mole Valley Farmers prime calf rearer nuts; 870g/kg dry matter (DM), 190g/kg crude protein (CP), barley straw (890g/kg DM, 30g/kg CP) and grass hay (890g/kg DM, 60g/kg CP) in raised feeders (hay and straw feeders L:590mm W:430mm H:565mm; creep feeder L:590mm W:590mm H:580mm – all mounted with the base 500mm from the floor) from 14 days of age. Animals were fed with one milk teat per pen, connected to a Förster-Technik Vario smart milk feeder (Förster-Technik, Engen, Germany). Volac Blossom Hi-Spec milk powder (250g/kg CP) was fed at 38 degrees Celsius at a mixing rate that gave 150g/kg DM. Once per day the milk feeder components and feeding station were

cleaned with a sterilising solution. Physical enrichment was provided in the form of one wooden cable spool per pen.

Kids were kept within a 2.44 x 2.44 m (5.95m^2) pen for the first five days and assisted to feed four times/day; when a kid was recorded successfully feeding without help, training ceased for that kid. Each pen was then enlarged to 3.66 x 3.66m (13.40m^2) for the study duration, giving a minimum stocking density of 1.49m2/kid (greater area per kid than the recommended 0.9m2/kid for kids >8wks of age (NFACC, 2022). Data collection began when the kids were 15 days of age for solid feed and water intake, and 22 days of age for milk feeding records – this allowed sufficient time for the kids to acclimatise to the setting and the ad libitum milk feeding system, be reliably teat trained, and allow reliable RFID detection (via the standard ear tags fitted for management and to comply with UK traceability legislation) of individual kids. At 1700hrs at a pen average of 56 days old (56d + 4d) full abrupt weaning (removal of all milk access) occurred (abrupt weaning was chosen to be reflective of standard UK commercial practice: Anzuino et al., 2019; Vickery et al., 2022).

5.3.2 Measures of health

In addition to daily visual monitoring of kids, during weekly weighing sessions a health examination occurred including ocular and nasal discharge, ear droop, induced cough, audible lung sounds, faecal soiling, and ‘other’ health concerns. The examination was adapted from the Animal Welfare Indicators Project (AWIN) welfare assessment for lactating dairy goats, 2015, and the Calf Health Scorer app (University of Wisconsin), and symptoms were scored as either ‘present’ (score of one) or ‘absent’ (score of zero). If a kid scored >3, at any one point once the study began, it would be considered ‘sick,’ and its data removed from analysis – however this did not occur.

5.3.3 Measuring milk intake and feeding behaviour

Milk intakes were recorded via specially fabricated milk feeding stations (W: 195mm, H: 700mm, L: 600mm, teat set at 450mm from floor: Figure 5-1) made from steel and lined with hygienic parlour board. These stations allowed one kid access to the teat at a time, and built-in Radio Frequency Identification (RFID) readers recorded kids' individual ear tag identification. A kidney dialysis pump was triggered by suckling and each turn of the pump was recorded as dispensing 5+0.05 ml of milk. Monitoring occurred for 24hrs/day; time, duration, milk intake and kid ID were recorded for each visit; these data were continuously stored via the Förster-Technik 'CalfApp GO'.

Figure 5-1. An image of the milk feeding station (W: 195 mm, H: 700 mm, L: 600 mm, teat set at 450 mm from floor) for the goat kids reared artificially on a computerised ad libitum milk supply.

5.3.4 Solid feed and water intake

Between 0830 and 1000 each day, solid feed refusals from the previous day were removed and weighed (±1g), fresh feed was then weighed (±1g), and added. Daily feed intake (kg DM as fed/kid) was calculated as: kg DM feed offered - kg DM refusals. Water intake was measured in the same way; the water bucket was mounted to the wall to minimise spillage but if the bucket had been disturbed, data was not recorded for that day.

5.3.5 Weight gain measurement

Kid enrolment weights were recorded upon arrival when kids were placed inside a canvas bag which was suspended from a Weighmate® digital scale (tared to include the bag

weight), then kids were weighed weekly using a Marsden V-100 veterinary scale, until ten weeks old.

5.3.6 Video observations

A Swann four-camera CCTV system (1080p Full HD DVR-4580 with 1TB HDD) recorded footage for six hrs/day (1000-1200; 1330-1530; 1630-1830) which was downloaded and stored in external hard drives. All focal kids could be individually differentiated and were continuously observed during the observation periods. A behavioural ethogram of target behaviours was created (Table 5-1) focusing on behaviours related to Feeding Competition (queueing for feed station access; unsuccessful and successful displacements from the milk feeding station), Milk Feeding (enters and exits milk feeding station), and Solid Feeding (feeding on hay, creep, or straw). All behaviour groups were analysed pre-weaning, but only solid feeding was analysed post-weaning (when milk access was removed). CCTV malfunctions resulted in missing days and corrupt footage which could not be analysed, consequently only nine days across the study could be selected; five days pre weaning (Pen 1: age 24 and 25 days, 35 and 36 days, 45 days; Pen 2: age 24 days, 35 and 36 days, 45 and 46 days) and four days post weaning (57, 58, 66 and 67 days of age for both pens).

Table 5-1. Ethogram of behaviours recorded via video observations of goat kids reared artificially on an ad libitum milk supply system.

Category	Parameter	Description
Feeding Competition	Queue for feed station access	Kid waits within one body length of the milk station entrance, whilst another kid is inside, with head orientated towards the entrance.
	Attempt displacement (unsuccessful)	Kid contacts the body of the kid that is inside the feed station but the kid within the station does not exit.
	Attempt displacement (successful)	Kid contacts the body of the kid that is inside the feed station and the kid within the station exits.
Milk feeding	Enters milk feeding station	Kid walks into the milk feeding station and is counted as having entered when its head and shoulders are inside the station and no longer visible.
	Exits milk feeding station	Kid reverses out of the milk feeding station and is counted as having exited when its head becomes visible outside of the station.
Solid Feeding	Hay feeding	Kid is orientated so that its mouth is within one muzzle length of the hay feeder or is actively feeding from the hay feeder.
	Straw feeding	Kid is orientated so that its mouth is within one muzzle length of the straw feeder or is actively feeding from the straw feeder.

Creep feeding	Kid is orientated so that its mouth is within one muzzle length of the creep feeder or is actively feeding from the creep feeder.

5.3.7 Missing data

Milk intake was monitored twice daily and if a kid had not consumed milk by 1000hrs, or if by 2000hrs a kid was <50% of the average milk consumption of other kids in the pen, they were encouraged to feed and the milk feeding data was removed for that kid for that day. This resulted in two one-day removals of milk feeding data for two kids. Two days of creep feed intake were unable to be recorded due to spillage. Five days of water intake were not recorded due to spillage or data sheet damage.

5.3.8 Statistical analysis

Data from 16 kids were analysed (seven from pen 1, and nine from pen 2 using IBM SPSS, version 25; SPSS Inc., Chicago, IL, USA. Average Daily Gain (ADG) was used to represent growth rate and calculated using weekly weights (Weight 2 – Weight 1/ days between weighing). The milk feeding period was between day 22 and day 55 (day 56 was not included as weaning occurred at 1700hrs). Model residuals were checked for normality using the Shapiro-Wilks statistic, and homogeneity of variance was assessed visually via scatter plots, some variables showed non-normality and heteroskedasticity, so analyses were repeated after applying normalising and stabilising transforms. Untransformed data are presented when results did not alter the statistical significance, in cases where the results were affected, we present the statistics for the transformed data (clearly noted in the presented results).

Solid feed intakes

Spearman's rank correlations were used to assess the relationship between pen-level daily feeding behaviour variables (Creep, Straw, Hay, and Water intakes) and age for the milk feeding period.

Evaluating milk feeding variables and Average Daily Gain

To investigate the relative importance of factors influencing ADG, the latter was used as the response variable in univariate general linear models with kid ID (nested within pen) and week treated as fixed factors, and all other possible explanatory variables presented as daily averages per week of the study (milk duration, rewarded visits, unrewarded visits, and unrewarded duration) treated as covariates. The optimum model was developed using a stepwise elimination of the least significant explanatory variable until all predictors showed a significant effect (residual maximum likelihood analysis: Searle et al., 2009).

Individual meal criterion

Gaps between feeding times were defined to be the duration from the end of one visit to the start of the next. A mixture of two Gaussians was fitted to the log of the intervals between individual visits, and visits that belonged by maximum likelihood to the first Gaussian were compressed into a single individual meal as in David et al., (2014). To investigate the patterns of individual feeding, the same six metrics as in David et al. (2014) were computed, these were:

- the number of visits making up that meal,
- duration of that meal and
- total milk consumed during that meal.

These were aggregated into daily individual kid summaries capturing:

- the number of meals per day,
- the total feeding duration per day,
- total milk consumption per day.

To each of these metrics, a mixed model was fitted, with week (polynomial contrasts), pen (sum contrasts) and their interaction as fixed factors, and kid IDs and dates modelled as random factors. Random slopes for the week effect were also included within the kid random effect, as well as the random intercepts. After careful model simplification to remove singularities (following the approach of Matuschek et al., 2017), estimated marginal means per week, omnibus p-values and linear contrasts were obtained. Further, for each of the metrics, correlations per-kid were calculated, along with repeatabilities, which were calculated using mixed models according to the IntraClass Correlation Coefficient (ICC) (2,1) metric of McGraw and Wong, (1996), with kid ID and date modelled as random factors. This was determined the natural measure of repeatability for the daily measures since daily conditions may impact feeding.

Social meal criterion

A similar approach was used to identify whether kids feed in “social meals”— visits in which several individuals choose to feed temporally close together. Time gaps between the end of a visit and start of next visit were calculated between all kids within a pen, to measure the lengths of time the feeder remained empty. A mixture of two Gaussians were fitted to the logarithms of all >0 s time gaps, and the intersection of the Gaussian curves used to identify a time threshold below which two visits might be considered part of the same social meal. The

number of kids attending each social meal and the duration of time spent and quantity of milk consumed in social meals of different sizes was calculated.

Video observations

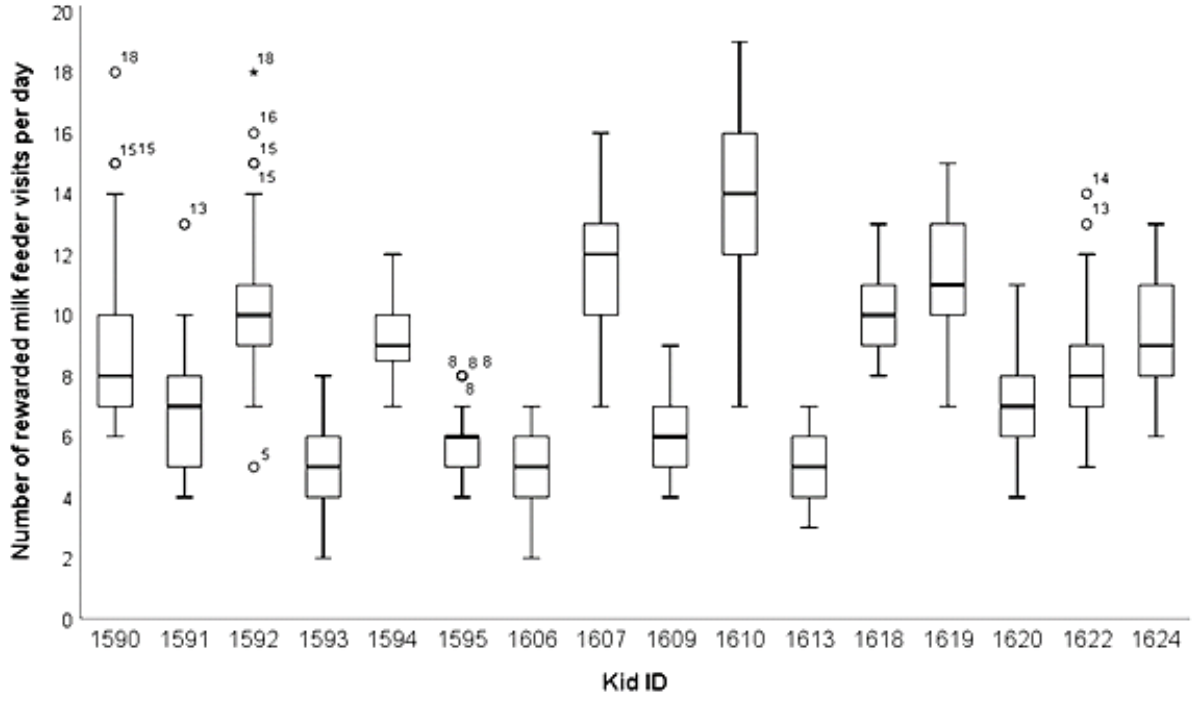
The two consecutive observation days were combined and averaged (per day) to give five values per kid, per pen (three pre-weaning, two post-weaning). These five periods were analysed using a mixed model, with kid ID (with random slope and intercept included) as random factor, and period, pen, and period*pen as fixed factors to generate estimated marginal means for all duration-based variables (feeding on straw, creep, or hay).

5.4 Results

5.4.1 Describing milk feeding behaviour

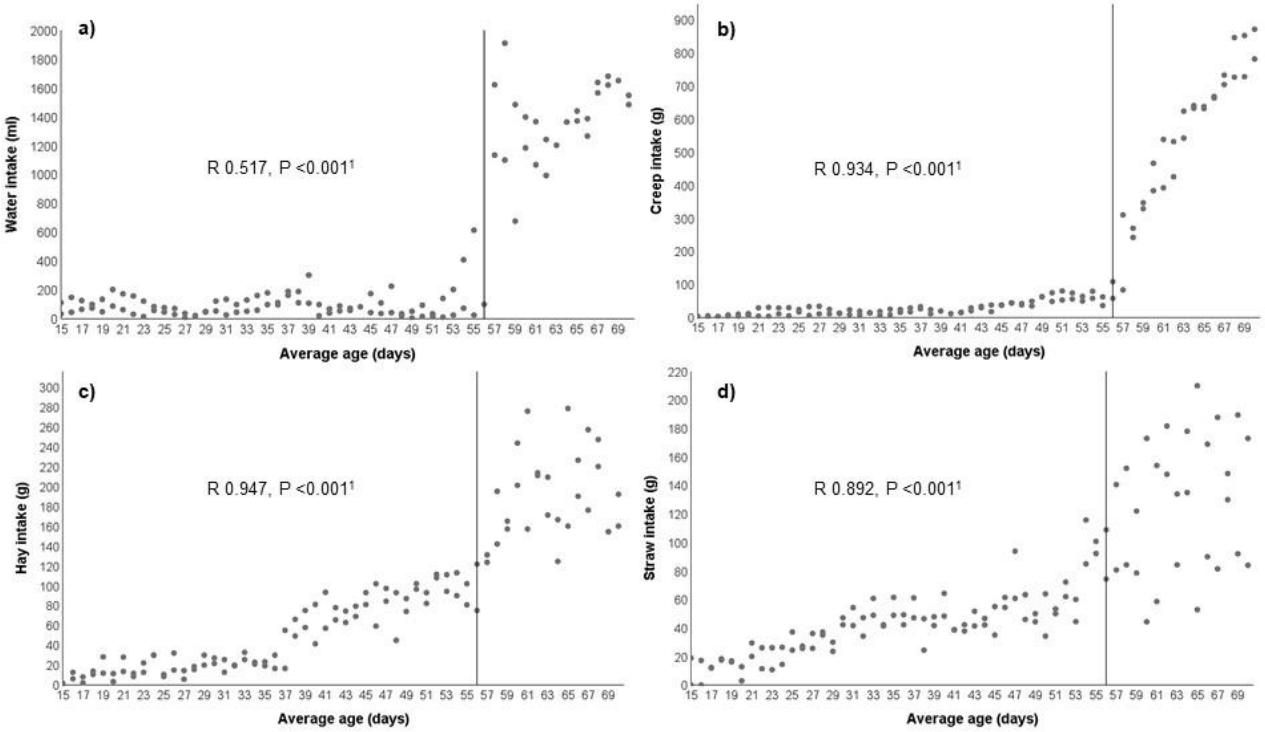
On average it took 7.75 days before kids were reliably consuming milk without human assistance, with a range from 2-15 days. Of the 5619 milk station visits recorded for the 16 kids across the milk feeding period 4434 (78.9%) were ‘rewarded’ (milk intake occurred). The remaining 1185 (21.1%), were ‘unrewarded’ (no milk intake took place), occurring an average of 2.29±0.114 times daily (range 0-15 per kid). Across the study milk feeding was recorded in every hour of the day, with no peaks observed in any hour. The mean number of daily rewarded visits to the milk station per kid was 8.39±0.139 (range 2-19) and when observed by kid, there were visible differences in the feeding behaviour of individuals (Figure 5-2), with some consistently visiting the feeding station fewer times per day (for example see ‘kid ID 1593, 1606, 1609 and 1613). Across the study a large range in daily milk intakes was observed (average individual intakes from 1382-2690ml/day).

Figure 5-2. Box plot of number of the daily number of rewarded feeder visits of each individual kid (n = 16) artificially reared on an ad libitum milk feeding system and weaned at 56 days of age.



5.4.2 Solid feed intakes

All measures of solid feed and water intake were positively correlated with age (days) for the milk feeding period (d22-55) (Figure 5-3), and sudden and steep increases in intakes are visible in weeks nine and ten when kids had no milk access.



[1]Spearman rank correlations were not calculated after day 56 due to the impact of weaning increasing consumptions

Figure 5-3. Pen level (n = 4 pens) daily water (a), creep (b), hay (c) and straw (d) intakes for goat kids reared on a computerised milk-feeder with free-choice ad libitum feed and weaned from milk at 56 days of age (indicated with a solid marker line) with Spearman rank correlation results displayed for days 15-55.

5.4.3 Evaluating Average Daily Gain

ADG was most significantly impacted by an interaction between average daily milk intake and week (p <0.001, Figure 5-4), and was not significantly affected by week alone (p 0.226, Estimated Marginal Means (EMM): 0.19 week 4; 0.21 week 5, 0.22 week 6 and 7, 0.20 week 8, 0.19 weeks 9 and 10). With all possible explanatory variables included the R2 value was 0.464, F 16.247 and p values were: Week 0.010, Milk intake <0.001, Duration of time spent milk feeding 0.721, and Number of rewarded milk station visits 0.124). Average kid weights in week 4 (first week recording milk intake) were 8.04±1.471 kg (Pen 1) and 9.43±1.719 kg (Pen 2) and milk intake as percentage of liveweight averaged 2.0±0.23% (Pen 1, range: 1.7-2.4%) and 1.8±0.20% (Pen 2, range: 1.5-2.1%). By week 8 (the last weight before milk weaning occurred) kids weighed on average 14.29±2.094 kg (Pen 1) and 14.99±2.613 kg (Pen 2), milk intake as percentage of liveweight averaged 1.4±0.23% (Pen 1, range: 1.0-1.7%) and 1.3±0.13% (Pen 2, range 1.0-1.5%).

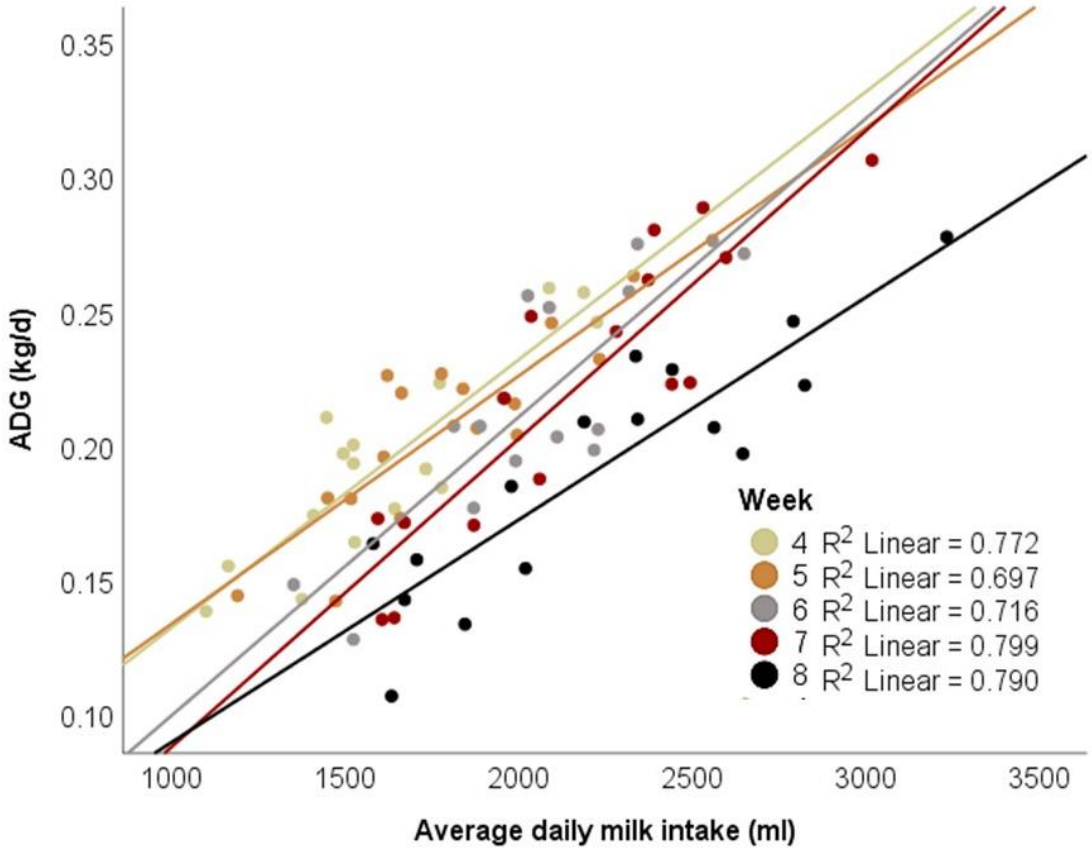


Figure 5-4. Relationships between goat kids' predicted values for Average Daily Gain (ADG; kg/d) and average daily milk intake (ml) per week of age when reared on ad libitum milk, creep, straw, and hay; all weeks significant to $p<0.001$. Marker dots indicate each kid (n = 16).

5.4.4 Individual milk meals

The fit of the Gaussian mixture model for individual meals identified a threshold value of 1hr 24 min to separate milk station visits into individual meals (Figure 5-5).

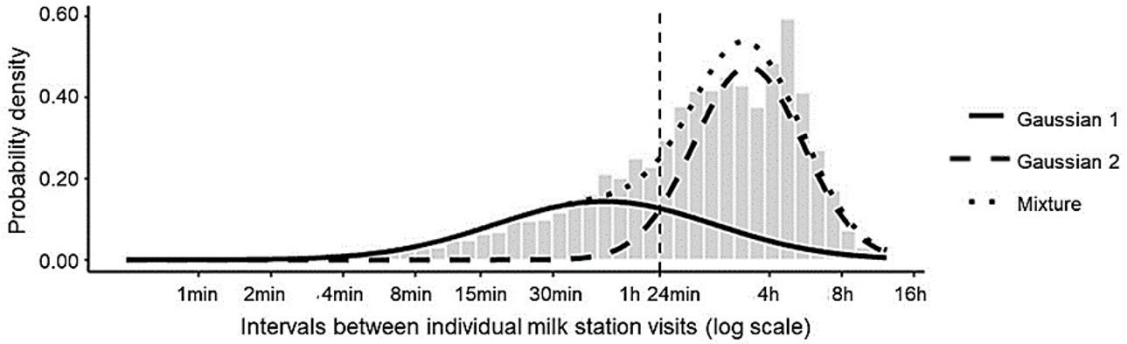


Figure 5-5. Fit of a probability density function of a mixture of Gaussian distributions on the log-transformed gaps between individual goat kid (n = 16) milk meals.

EMMs (weekly) and omnibus tests from the mixed models revealed that daily milk intake showed a significant increase over time, as did milk intake per meal, however, the meals did not grow in length, nor were there more meals per day (Table 5-2).

Table 5-2. Estimated Marginal Means (with standard errors in parentheses) of milk-feeding variables for 16 individual goat kid meal metrics when reared on ad libitum milk from a computerised feeder and weaned at 56 days of age.

Variable	Weeks					p values[1]	
	4	5	6	7	8	Week	Week*Pen
Feeding events /meal (n)	1.4 (0.09)	1.4 (0.08)	1.5 (0.09)	1.3 (0.09)	1.4 (0.09)	0.104	0.948
Meals per day (n)	5.9 (0.28)	5.8 (0.28)	6.0 (0.28)	5.9 (0.26)	5.8 (0.25)	0.666	0.049*
Length of 'meals' (min)	4.2 (0.27)	4.2 (0.19)	4.2 (0.19)	3.9 (0.19)	4.1 (0.24)	0.311	0.836
Feeding time /day (min)	24.5 (2.09)	24.5 (1.73)	25.6 (1.71)	23.0 (1.61)	24.2 (1.85)	0.095	0.232
Milk intake /meal (ml)	289 (18.6)	317 (19.8)	348 (20.0)	373 (20.4)	387 (24.6)	<0.001	0.085
Milk intake /day (ml)	1623 (86.9)	1781 (83.8)	2056 (91.7)	2160 (110.3)	2222 (125.1)	<0.001	0.040*

[1]p values are stated for 'Week' and 'Week*Pen' only, as values for 'Pen' were all >0.436
* indicates significant differences at the alpha value of <0.05 (5%)

Table 5-3 shows that individual meal metrics have lower repeatability than daily metrics (ICC (2, 1) repeatability measures: No. of feeding events/ meal 0.09, Length of meals 0.04, and Milk intake/ meal 0.17 versus No. of meals/ day 0.43, Time spent feeding/ day 0.49, and Milk intake/ day 0.63).

Table 5-3. ICC (2, 1) repeatability measures on the main diagonal (**bold**), and inter-kid correlations on the off diagonal, of the six metrics of individual goat kid feeding behaviour (n = 16).

	No. of feeding events /meal	No. of meals /day	Length of meals	Time spent feeding /day	Milk intake /meal	Milk intake /day
No. of feeding events /meal	**0.09**	0.72	0.88	0.90	-0.72	-0.21
No. of meals /day		**0.43**	0.56	0.92	-0.63	0.13
Length of meals			**0.04**	0.84	-0.54	-0.13
Time spent feeding /day				**0.49**	-0.66	0.03
Milk intake /meal					**0.17**	0.68
Milk intake /day						**0.63**

5.4.5 Social milk meals

The Gaussian mixture fitted to social meals identified a threshold value of 3 min 10 s (Figure 5-5), therefore if the milk station was empty for less than that between two visits, those visits were considered part of the same "social meal". This criterion identified an average of 35 daily meals, with an average of 1.9 kids at each social meal. Following the analysis of David et al. (2014), our study found that 57% of "social meals" were attended alone; 21% had two kids in attendance, 10% had three and only 12% of meals >4 kids in attendance. However, when considering meals as the percentage of milk intake consumed, meals with more kids in attendance result in higher milk consumptions than a solo session. The average percentage of meals each kid attended of different sizes, found that on average a kid went to 28% alone (accounting for 26% of their milk intake), whereas 74% of milk consumption occurred during meals with >2 kids present, and 67% of time spent at the feeder was as part of social meals with >2 kids.

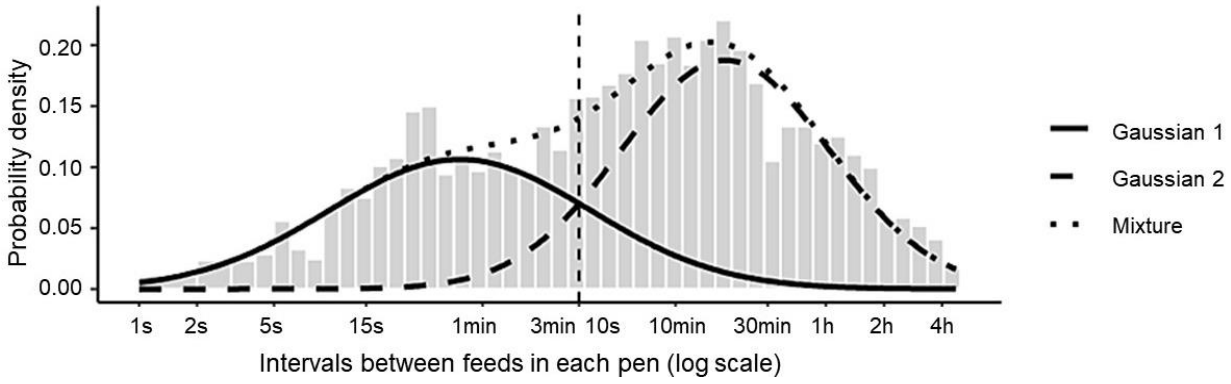


Figure 5-5. Fit of a probability density function of a mixture of Gaussian distributions on the log-transformed gaps between social goat kid milk meals (n = 16).

Figure 5-6 shows that most kids followed a similar pattern in the number and size of social meals attended but three show distinct individuality with a lower probability of feeding alone than most other kids.

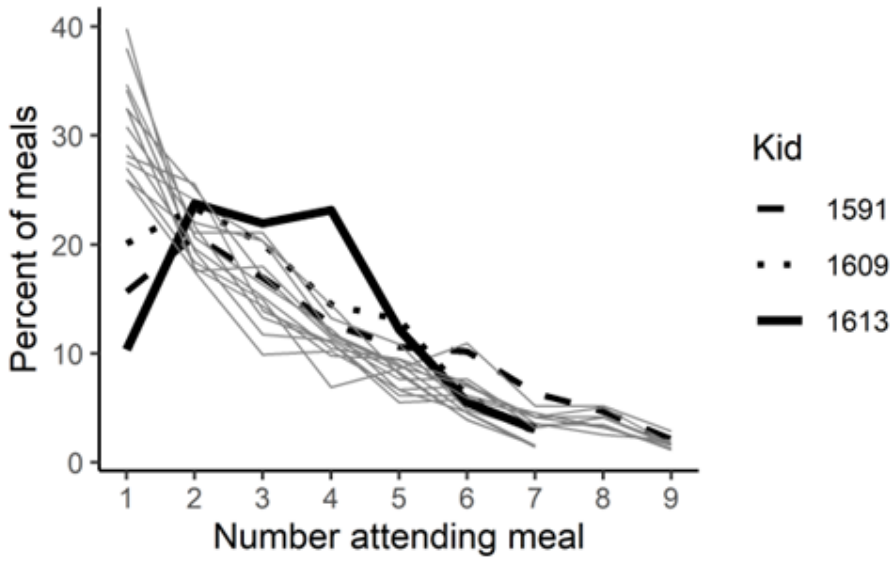


Figure 5-6. The likelihood of 16 artificially reared goat kids to suckle the milk teat within different sized “social meals”.

5.4.6 Video observations

The milk feeding system was validated against behavioural observations; all incidences when the kid was observed entering the milk feeding station were accurately identified in <22 s. Across the observations 22 occasions where a kid visibly entered the milk station but was not identified by the machine were recorded, these visits lasted <34 s and are explained by kids entering the station, but not feeding or placing their heads far enough forwards for the RFID reader to register their ear tag. Attempted displacements from the milk station were observed 46 times (Pen 1: 34, Pen 2: 12) across the five pre-weaning days and successful displacements were observed 7 times (Pen 1: 5, Pen 2: 2). On average kids in Pen 1 queued for access to the milk station for 21.18±5.788 s and Pen 2 for 17.63±5.135 s in each six-hour preweaning observation period. The amount of time spent feeding on solid feeds significantly increased over time, with the largest increase seen between pre and post weaning periods (Table 5-4).

Table 5-4. Estimated Marginal Means (with 95% confidence intervals) of time spent feeding (minutes) per six-hour observation period of 16 individual goat kids when reared on ad libitum feed and water and weaned at 56 days of age.

	Period							
	PreWean		PostWean			p values		
Variable	**1**	**2**	**3**	**4**	**5**	**Period**	**Period* Pen**	**Pen**
Creep[1]	2.1 (0.1, 0.2)	4.3 (0.2, 0.3)	6.2 (0.3, 0.4)	22.9 (0.6, 0.7)	31.2 (0.7, 0.8)	<0.001*	0.435	0.060
Straw	3.7 (0.8, 14.3)	5.6 (6.6, 20.1)	21.7 (10.8, 24.3)	40.3 (17.6, 31.1)	26.9 (19.4, 32.9)	<0.001*	<0.001*	0.929
Hay	7.5 (-2.1, 9.4)	13.3 (-0.1, 11.4)	17.6 (16.0, 27.5)	24.3 (34.6, 46.1)	26.2 (21.2, 32.7)	0.001*	0.098	0.004*

[1]Values for creep are presented from a square root transformation as this was required to ensure the model met assumptions and altered significance levels, estimated marginal means have been back transformed.

* indicates significant differences at the alpha value of <0.05 (5%)

5.5 Discussion

Our study is the first to quantify the milk feeding behaviour of goat kids reared away from their dams on ad libitum milk. Findings show that milk intake continuously rises until weaning at 56 days of age, which as expected coincides with a sudden, substantial increase in solid feed and water consumption and time spent feeding on solid feeds. A meal criterion of 1hr 24min and 3min 10s was identified for individual and social-level meals respectively. Number of individual daily milk meals was consistent over time but varied between individuals. The most significant predictor of ADG identified was an interaction between milk intake and week, as milk intake was positively correlated with age. Variations in individual feeding behaviour that could impact productivity warrant further consideration.

Our kids varied considerably in their ability to learn to use the milk feeding system, with some feeding independently within two days of arrival and others taking up to 15 days (average: 7.75 days), this alongside two kids squeezing into the milk station together when young meant milk feeding variables were not recorded until later than originally planned. There are limited studies describing adaptation to an artificial milk feeding system in small ruminant species; however, Veissier and Stefanova, (1993) found that lambs learned to suckle from an artificial teat faster when grouped with lambs that had previously learned this behaviour (lambs with experienced partners learnt within three days, whereas those without took up to nine).

Therefore, it seems likely that despite potential species differences, our kids were also impacted by their collective naivety, as it took considerable time for them to begin suckling independently.

Once kids had learnt to use the system the proportion of unrewarded visits (21.1%) was similar to the 27% reported by David et al. (2014) of artificially reared lambs. Whilst it has been suggested that unrewarded visits indicate hunger (De Paula Vieira et al., 2008), milk was available ad libitum for our study and David et al. (2014) so the cause of these visits remains unknown and was not hypothesised upon by David et al. (2014). However, the environment of the milk feeding station differed to their home pen (plastic sides, metal fixings, and wood shaving floor) and as the behavioural observations showed kids licking the sides and chewing on wood shavings within this area, we suggest in this case some unrewarded visits may reflect a desire to spend time engaged in exploration-based behaviours.

The number of rewarded visits to the milk feeder remained consistent at around 8/day throughout the study; similar to the results published for artificially reared calves (around 10/d: Appleby et al., 2001; von Keyserlingk et al., 2004). This is markedly different from dam-reared lambs, (22 times in 16 hours: Munro, 1956), and whilst this could be due to species-specific differences there is no research regarding goat kids dam-reared, suggesting that behavioural differences could be caused by artificial versus natural rearing. This may be due to the consistency of artificial milk supply compared to the variable nature of dam milk supply which impacts suckling behaviour (Day et al., 1987), and a lack of dam related cues that reduce milk intake, as calves age dam terminated suckling bouts increase (Reinhardt and Reinhardt, 1981).

When structured into individual meals, our goat kids fed in fewer meals than artificially reared lambs (5.9 versus 9.5: David et al., 2014). Despite using the same methodology our threshold value for the meal criterion was longer (1hr 24min versus 49min: David et al., (2014)), however our study had the same average number of feeding events per meal (1.4); therefore it appears this longer criterion and species difference had little impact on meal averages. No preferential milk feeding times were observed throughout the day, which agrees with evidence from artificially reared lambs (David et al., 2014) and calves (Borderas et al., 2009), and shows that for individuals to fulfil their preferred milk intake patterns, access to a milk feeding station should be provided throughout a full 24-hour period.

The average number of daily individual milk meals (5.9) shows a considerable difference from how kids are reared in meal-based systems – as internationally most farmers reported (78.3%) feeding three or four meals daily, with 10% feeding two, and 89.5% further decreasing the daily number of meals after eight days (Vickery et al., 2022). Our study found differences in the number of daily milk meals each kid consumed (Figure 5-1), suggesting individual variation in the coping ability of kids reared on a restricted meal-based system. Our goat kids also varied considerably in the amount of milk they consumed when available ad

libitum (intake from 1.4 to 2.7 L/day), and this individuality could contribute to observed differences in growth rates (ADG from 0.12 to 0.22 kg: Figure 5-3), however some of this variation could be explained by reporting milk intake as a percentage of bodyweight, which in week 4 had a slightly smaller range (1.5 to 2.4%). Similar variability has been reported in calves (milk intake from 2.4 to 12 L/day; ADG from 0.07 to 1.2 kg; Rushen, 2016) and lambs (milk intake from 0.3 to 2.9 L/day; David et al., 2014). Practical constraints limited our study to collecting data from only male goat kids, and this should be considered when generalising the results. There is limited information regarding how sex affects ruminant milk feeding behaviour, however David et al. (2014) found that lamb sex impacted daily number of milk meals and intake per meal (females eating smaller amounts more frequently, which agrees with pig research: De Haer and De Vries, 1993) but did not influence time spent milk feeding, overall milk intake or feed conversion efficiency. This suggests that daily number of meals fed could impact female goat kids more severely.

Each day, kids spent on average 23.0 to 25.6 minutes milk feeding, and as they aged the time spent feeding and number of daily meals did not significantly change but they did increase the quantity of milk they consumed per meal and per day. No correlation was found between daily time spent feeding and overall intake; however, findings indicate that individuals that visited the feeding station more frequently consumed less milk per meal and per day. The daily time spent feeding was lower than observed for artificially reared lambs (38.3 minutes: David et al., 2014), but similar to dam-reared lambs (24 min: Teke and Akdağ, 2011). David et al., (2014) reported that over time lambs increased the milk quantity consumed per meal, and per day, indicating that intake capacity and speed increase with age, which agrees with our findings for goat kids, but unlike our study the lambs reduced their time spent feeding, and number of daily meals. It should be noted that David et al. (2014) weaned lambs much younger than our study (28 days of age) and provided no access to solid feed during this time, whereas before weaning our kids spent on average 45.5 minutes out of six hours feeding on solid feedstuffs. The finding that individuals who visited the feeding station more frequently had lower intakes was not observed by David et al., (2014). This points to a need to further understand the individuality of goat kid feeding behaviour, additional investigation into this could help to understand why kids' responses vary and could contribute towards selection programmes aiming to identify and increase the genetics of individuals which are most able to cope with artificial rearing.

Rojo-Rubio et al. (2016) observed that dam-reared male dairy breed kids had an ADG slightly lower than observed in our study (190-220g versus 163g; Roja-Rubio et al., 2016) during the milk-feeding period, suggesting that weight gains of artificially reared kids are comparable to those reared naturally. Rojo-Rubio et al. (2016) observed that neither litter size or

breed (Anglo Nubian, Alpine or Saneen) had an impact on weight gain, therefore using crossbred kids in our study is unlikely to have impacted ADG. Our results may not be directly applicable to females due to their lower ADG (Davis et al. 1998; Rojo-Rubio et al. 2016) and milk intakes (Davis et al., 1998), however, this sex difference is not clear-cut as early castrated male kids (our kids were castrated in order to be rehoused) have lower ADG than intact males (Louca et al., 1977; Murray et al., 2001) and sex does not significantly impact weight in both dam and artificially reared kids studied up until 28 days old (Delgado-Pertíñez et al. 2009). It would be useful for future research to study female kids to investigate feeding behaviour differences and future productivity, as dairy calf research shows that early growth rates impact conception and milk yields (reviewed by Khan et al., 2011). Understanding how to achieve optimal growth rates is essential to rearing healthy and productive animals, which has wider environmental impacts (faster growing animals capable of conceiving younger have a lower overall carbon footprint: Bell et al., 2015).

Regarding social meals, our threshold value was lower than David et al., (2014) (3 min 10 s versus 22 min 30 s) as our criterion used the amount of time the feeder spent empty, from the end of one visit to the start of the next, whereas David et al. (2014) calculated start to start time intervals. This could explain why we saw less evidence of 'social' meals compared to David et al., (2014) who observed that 65% of lambs wanted to access milk during the same meal, however their study had a slightly higher number of individuals per teat (8-15 versus 7-9 in our study) and provided no solid feed, which could have increased milk competition. No other research is available on social meal criterions of milk-feeding for comparison. Interestingly whilst only 42% of 'social' meals had >2 kids in attendance, 74% of milk was consumed during these meals, showing that kids drank more when attending a social meal versus feeding alone which suggests that feeding competition does not detrimentally impact milk intake for the kid to teat ratio used in our study. This is supported by the small number of observed displacements from the milk station, and minimal amounts of time spent queueing for milk access (average: 19.63 seconds/six-hour observation), evidencing that the generous stocking density allowed for our kids likely minimised feeding competition.

Our goat kids reared on ad libitum milk had low solid feed intakes at weaning (compared to current guidelines) which likely impacted their rumen development and ability to compensate for the loss of milk nutrients at weaning; however, a noticeable growth check was not observed, and we were unable to directly measure rumen development. Most artificially reared kids are weaned at 56 days of age (UK, Anzuino et al. 2019; Canada, Bélanger-Naud et al. 2021) so this study weaned at the same age, to ensure comparability to commercial conditions in the United Kingdom. Early weaning is common in artificial systems due to the high cost of milk replacement and the labour-intensive nature of the milk-feeding period. Young ruminants who

are slow to transition to solid feeds show impaired growth (lambs: David et al., 2014; goat kids: Warmington and Kirton, 1990), as solid feed intakes are positively correlated with rumen development (goat kids: Hamada et al., 1976). Hart and Delaney (2016) suggest a kid must have concentrate feed intakes of >250g day at weaning; a widely used industry guideline for lambs that is commonly transferred to goat kids (Volac, 2019). Yet at the industry standard weaning age, our kids were only spending 6.2 minutes within six hours at the creep feeder and consuming 64 g/d of creep feed, which rapidly increased by >600% to 392 g/d when milk access was removed. Social learning plays a significant role in the development of ruminant feeding behaviour (Launchbaugh and Howery, 2005); for example, naïve calves show increased grazing when with an older, experienced companion (Hessle, 2009). Research shows that feed intakes are affected by individual behaviour (von Keyserlingk and Weary, 2010), that develops early in life (Provenza and Balph, 1987), and rearing goat kids in groups of naïve individuals is likely to impact solid feed intake.

5.6 Conclusions

Kids showed marked differences in their milk feeding behaviour and understanding this individuality would be beneficial and could inform further research that aims to provide management information regarding reducing weight gain variability, improving productivity and individual kid welfare. There was little evidence of close, consecutive feeding however, kids consumed more milk in ‘social’ meals, and combined with behavioural evidence this suggests that milk-feeding competition was not problematic with 7 to 9 kids per milk teat. Solid feed intakes and time spent solid-feeding pre-weaning were concerningly low and could have been impacted by a lack of experienced social models, yet goat kids reared on ad libitum milk achieved weight gains comparable to those reported in kids reared with their dams. Whilst this study should be interpreted with caution since it was small-scale and used only male mixed dairy breed kids, it utilises formerly unused technology to provide previously unknown information that has established an important baseline for future work in this understudied species.

5.7 Ethics approval

Ethical approval was granted by the University of Reading, School of Agriculture, Policy, and Development (reference number 001561) and Dalhousie University (reference number 2021-010).

5.8 Acknowledgements

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6. Gradually weaning goat kids may improve weight gains whilst reducing weaning stress and increasing creep feed intakes

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It is estimated that the first author H M Vickery contributed approximately 85% of the work including conceptualization, methodology, data collection, analysing results and fully preparing the first draft. Authors R K Meagher, S Stergiadis and R A Neal provided supervision, assistance with finalising methodology and provided review and editing of the written paper draft.

6.1 Abstract

Most dairy goat farms rear kids on ad libitum milk replacer. Calf research suggests this improves growth and welfare, but solid feed intakes are problematic. Weaning can be gradual (incremental milk reduction) or abrupt (sudden, complete milk removal, which evidence suggests reduces welfare). Three treatments were created; abrupt weaning (AW: ad libitum milk until weaning), gradual weaning (milk ad libitum until d35, then milk unavailable 3.5h/d until d45 when milk removal was a 7h/d block (gradual weaning 1: GW1), or 2 x 3.5h/d blocks (gradual weaning 2; GW2)); complete milk removal occurred at d56 for all. Experiment 1 investigated on-farm feasibility, behaviour, and Average Daily Gain (ADG). Experiment 2 investigated feed intakes, behaviour and ADG for AW and GW2. Experiment 1 had 261 kids (nine pens of 25-32), CCTV recorded 6h/d and group-level scan sampling recorded target behaviours. Kruskal-Wallis tests showed GW2 kids spent more time feeding on solids during weaning ($p = 0.001$) and displayed lower levels of 'frustrated suckling motivation' PostWean ($p = 0.008$). However, feeding competition differed PreWeaning ($p = 0.007$). ADG data from 159 female kids analysed by a General Linear Model (fixed factor: treatment; covariate: 34d weight) found GW2 had highest ADG from 35-45d ($p = <0.001$), no differences from 45-56d and AW had highest ADG PostWean (56-60d). Experiment 2 had two AW pens (9 kids/pen) and two GW2 pens (8 and 9 kids/pen). A computerised feeder recorded milk intakes from 22-56d. Pen-level solid feed/water intakes were recorded from 14-70d. General Linear Models (fixed factor: treatment; covariate: PreWean value) found GW2 kids had higher ADG ($p = 0.046$) and lower milk intake ($p = 0.032$) from 45-55d, and PostWean (56-70d) trended towards GW2 higher ADG ($p = 0.074$). Mann-Whitney U tests showed pen-level feed intake differences: AW had higher creep and straw throughout, GW2 showed higher creep during weaning (35-55d), and higher water PostWean (>56 d). Behavioural observations suggest that gradually weaned kids may have enhanced welfare. Pen-level gradual weaning is feasible, and whilst weight gain results were mixed, it reduces milk intake, increases creep intake, and therefore combined with behavioural evidence can be recommended.

6.2 Introduction

On most commercial dairy goat farms, it is standard management to separate kids from their dams soon after birth (Anzuino et al., 2019; Belanger-Naud et al., 2021; Hempstead et al., 2021). With natural rearing of kids with their dams considered unviable both economically and practically for most commercial dairies, understanding how to optimise artificial feeding strategies for goat kids is essential for both welfare and productivity. Most dairy goat farmers use ad libitum milk feeding systems that allow constant, unrestricted access to milk (UK, Anzuino et al., 2019; Canada, Belanger-Naud et al., 2021; USA, Hempstead et al., 2021). Calf research suggests that animals fed on high milk intakes such as those achieved by ad libitum milk systems may have growth and welfare benefits compared to set-meal feeding, but lower solid feed intake and slower rumen development may be an issue, particularly during weaning (Terré et al., 2007; Weary et al., 2008) when individuals are expected to compensate for the loss of milk nutrients with increased solid feed intake. However, there is a lack of goat-specific research.

The weaning stage (the transition from milk to solid feed) represents an important period in the lifecycle of a young mammal, and management of this transition is crucial to productivity (Khan et al., 2011). In natural situations, goat kids become increasingly independent from around 35 days of age (Bungo et al., 1998), and are fully weaned between approximately 84 and 168 days (Collias, 1956). The natural weaning transition involves a gradually increasing number of suckling bouts terminated by the dam, occurring concomitantly with increased feed intakes (Reinhardt and Reinhardt, 1981). Social learning plays a significant role in the development of young ruminants' solid feeding behaviour (Provenza and Balph, 1987), yet within commercial systems, kids are typically housed in groups of very similar ages, hence with a lack of experienced role models, so allelomimicry plays a lesser role. Artificially reared kids are weaned from milk younger (UK: 42-56 days (Anzuino et al., 2019); 56 days (Vickery et al., 2022a)), and lack these social cues that cause them to gradually decrease milk consumption and increase solid feed intakes. This may contribute to the stress of weaning, which has been evidenced as causing reduced weight gain (Lu and Potchoiba, 1988; Newberry and Swanson, 2008) and the development of abnormal behaviours such as oral stereotypies (Atasoglu et al., 2008).

The process of weaning from artificial milk feeding systems can be conducted in different ways and the method used can influence growth rates (Roth et al., 2009; Weary et al., 2008, 2007). Vickery et al. (Vickery et al., 2022a) surveyed those rearing goat kids artificially for any purpose (other studies focused on commercial dairy farms) and found that abrupt weaning was used by 28.8%, but that abrupt weaning (the sudden and complete removal of milk) was significantly more likely if kids were reared on ad libitum milk systems, and that these are more

likely to be used by those rearing >100 kids per year. Bélanger-Naud et al. (2021) reported that in Canada 39% of surveyed farms reported using abrupt weaning, but authors did not investigate if this was related to number of kids reared or feeding method. Evidence from calves suggests that abrupt weaning from both restricted and ad libitum milk feeding systems results in lower growth rates than gradual weaning, where milk intake is incrementally reduced before complete removal (over 9 days postweaning: Sweeney et al., 2010; over 6 days postweaning: Steele et al., 2017)

Previous goat weaning studies have focused on age at weaning (Morand-Fehr, 1991) or weaning and separation from the dams (Sporkmann et al., 2012; Ugur et al., 2007). Only two have focused on methods of weaning from artificial milk supply systems. Magistrelli et al. (Magistrelli et al., 2013) investigated physiological parameters with a limited sample size of 11 kids gradually weaned by 48 days of age. Whilst the authors found no negative effect of weaning on weight gain and that physiological parameters were within normal ranges, there was no abrupt weaning control group and power was limited. Furthermore, whilst no abnormal behaviours were observed, no behavioural ethogram was given, and behavioural data was not included in statistical analysis. Zobel et al. (Zobel et al., 2019) gradually weaned kids by a reduction in milk volume, or milk concentration, and concluded that four days after weaning, weights did not differ. However, the kids were weaned at 84 days of age following a six-day gradual weaning period. As most artificially reared kids in the UK are weaned at 42-56 days of age (Anzuino et al., 2019; Vickery et al., 2022a), and in Canada at 56 days (Belanger-Naud et al., 2021; Vickery et al., 2022a), the findings may not be universally applicable but do show how important age considerations are.

Whilst the calf weaning literature forms a useful basis for other ruminant species, the opportunity to manage weaning at the individual level using data-driven and technological approaches that are commonplace on dairy cow farms (for example see Rutten et al., 2013), is not utilised for goat kids due to the relatively low economic worth of each individual and high investment required for this technology, and therefore its relevance is limited. Previous work has recommended that for the greatest research impact, participatory engagement should be used to ensure research addresses the needs of farmers (Rose et al., 2018; Vatta et al., 2011). On goat farms, automatic ad libitum feeders typically supply milk to multiple pens of kids of different ages, with individual intakes unknown, so species-specific pen level strategies are required by farmers (Vickery et al., 2022b). Furthermore, farmers hold concerns related to removing and replacing milk-teats (Vickery et al., 2022b) and this must be addressed in order to understand and communicate the risks and benefits of gradual weaning.

The present work hypothesised that gradual weaning would improve the welfare and growth rates of goat kids by better preparing the kids to cope with the complete removal of

access to milk by increasing the amount of solid feed ingested prior to weaning. This was investigated via two animal experiments and teat removal was chosen as a simple gradual weaning method feasible at pen-level. Experiment 1 aimed to determine the effects of two different gradual weaning schedules from an ad libitum milk feeding system on kid behaviour and Average Daily Gain (ADG) and its feasibility for use on a commercial farm. Experiment 2 investigated in more detail the most promising schedule of teat removal for gradual weaning identified in Experiment 1, by monitoring individual kid milk intake, alongside recording weight gain and pen-level water and solid feed intake. The aims were to determine if milk intake and weight gain are affected by weaning treatment, and if this impacted associated rearing costs.

6.3 Materials and methods: Experiment 1 – gradual weaning under commercial conditions

6.3.1 Animals and housing

Data were collected from March to June 2019 from a commercial dairy goat farm (herd size 2500 milking does) in Dorset, UK. Experiment 1 enrolled 261 goat kids (86 males, 175 females: herd genetics predominantly Saanen) when they were moved to the ad libitum milk feeding system after colostrum feeding, at approximately 3 days of age. The kids were housed in a purpose-built barn with identical single sex 4.9 x 3.7m pens (filled with kids born within 4 days of each other) of between 25 and 32 kids, bedded on straw that was replenished daily. Kids were cared for according to the standard protocol of the commercial farm, all females were disbudded by a veterinary surgeon at approximately 14 days of age, and all males were castrated via elastration at <7 days. Kids were vaccinated with Heptavac P+ at 3 and 6 weeks of age and received a dose of coccidiostat prior to weaning. Milk was provided (Volac Lamlac 240g/kg CP) ad libitum to two teats per pen via a Förster-Technik Eco Feeder, and ad libitum creep feed (a concentrate starter feed) (For Farmers Capri Start 180g/kg CP), water and grass hay were available from 14 days of age.

6.3.2 Experimental design and treatments

261 animals were allocated to three experimental treatments: 58 females and 27 males to Abrupt Weaning (AW), 57 females and 32 males to Gradual Weaning 1 (GW1), and 60 females and 27 males to Gradual Weaning 2 (GW2), on a continuous blocked design (the barn was divided by a passageway, with six pens along one side (AW, GW1, GW2; AW, GW1, GW2) and three the other side (GW2, GW1, AW)). There were three pens of 25 to 32 animals per treatment, giving a total of nine experimental pens (six containing females – two per treatment, and three containing males – one per treatment). Treatment differences were in milk availability (Table 6-1) achieved via the removal of the artificial milk teat (the teat was simply unscrewed

from its base and removed). All kids had complete milk removal at d 56, and the experiment ended at 60 d (when the farm moved the kids to another building and socially mixed them into one large group).

Table 6-1. Experimental design showing differences in milk availability across experimental periods for goat kids under different weaning treatments.

Weaning treatment	Experiment period			
	PreWean (0-34 d)	**Weaning1 (35-44 d)**	**Weaning2 (45-55 d)**	**PostWean (56 d+)**
Abrupt (AW)	*Ad libitum*	*Ad libitum*	*Ad libitum*	None
Gradual1 (GW1)	*Ad libitum*	Teats off 1100-1430h (3.5 h/24)	Teats off 1000-1700h (7 h/24)	None
Gradual2 (GW2)	*Ad libitum*	Teats off 1100-1430h (3.5 h/24)	Teats off 1100-1430h and 1700-2030h (Total 7 h/24)	None

6.3.3 Weight gain

Individual weight gain data could only be collected from the female kids (174) due to the farm's use of individual identification tags. Whilst it was intended to collect enrolment weights once each pen was filled, due to kids being moved between pens unexpectedly when they first arrived this was not possible. The average birth date per pen was calculated and based on this, kids were weighed at a pen average of age 35 (when treatments commenced), 45, 56 and 60 d. Weights were used to calculate ADG for each of the experiment periods Weaning1 (35-45 d), Weaning2 (45-56 d), and PostWean (56-60 d).

6.3.4 Measures of health

Individual health observations (ocular discharge; nasal discharge; ear droop; cough during handling; audible lung sounds; faecal soiling; other health concern) were scored as symptom 'present' (score = 1) , or 'absent' (score = 0) at each weighing, enabling measures of health incidences to be analysed between treatments, and to identify 'sick' kids (kids scoring >3 at any one time) and remove their data from weight-gain analysis. Some health measures were adapted from relevant measures within the Animal Welfare Indicators Project (AWIN) welfare assessment for adult lactating dairy goats (2015).

6.3.5 Behavioural observations

A Swann four-camera CCTV system (1080p Full HD DVR-4580 with 1TB HDD) was fitted providing coverage of seven out of the nine experiment pens (three pens AW; two pens GW1; two pens GW2). The system recorded for six hours/day, in three blocks designed to capture teat replacement/removal times whilst avoiding times when workers were present (1000-1200; 1330-1530; 1930-2130); footage was downloaded and stored in external hard drives. A behavioural ethogram of target behaviours was created (Table 6-2). Definitions of behaviour were obtained from ethograms of calf behaviour (Jensen et al., 2007: competition related behaviours, Duve et al., 2012: play related behaviour descriptions – which were combined into social and locomotor play categories for our ethogram) and goat kid behaviour (Atasoglu et al., 2008: abnormal oral activities which became 'oral behaviours' in our ethogram). These behavioural descriptions were adjusted for relevance to our specific pen layout and goat kids according to initial observations of the video footage (Table 6-2). Pen-level scan sampling (five-minute intervals) was used to analyse the footage: due to the limitations of working on a commercial farm the kids could not be marked for individual identification; therefore, the number of kids performing each behaviour at the time of the scan was recorded and transformed into the percentage of kids in each pen performing each behaviour.

Table 6-2. An ethogram of the target behaviours recorded for artificially reared goat kids under different weaning treatments during Experiment 1.

Category	Parameter	Description
General play	Locomotor play	Energetic movements including running, twisting, jumping, and leaping.
	Social play	Interaction between >two individuals which are both engaged, including head butting, mounting and/or nudging. Differentiated from aggression by the interspersion of head butting with other behaviour.
Frustrated suckling motivation	Oral behaviours	The mouth can be seen in contact with the pen structure, and the tongue or jaw is moving suggesting that the individual is licking/chewing.
	Touch teat area	Kids face contacts the teat base/area within a head length of the teat base, regardless of if the teat is present or absent.
Feeding competition	Queue for teats	Kid waits within one body length of the teats, whilst others suckle, with head orientated in the direction of the teats.
	Push off teats	Kid contacts the body of the kid that is suckling.
Feeding	Activity towards forage	Kids body is orientated in such a way that its head (visible or not visible) is expected to be close to the forage.
	Activity towards creep feed	Kid has its head within the plastic structure of the creep feeder.

Four d/week were initially analysed for the first week of analysis (all pens – week 3), and a split half analysis (a correlation comparison between behaviours recorded on days 1 and 3 versus 2 and 4) was performed to check for consistency; all were significantly correlated, therefore analysis was reduced to 2 d/week. Each experiment period was analysed; PreWean (weeks 2, 3 and 4) were analysed at +2 and 5 d for each week (+/- 48 hours due to management related disturbances). Each of the two, 10-d treatment periods (Weaning1 and Weaning2) were analysed at +3, 6 and 9 d (start date being average birth date +35 d for Weaning1 and +45 d for Weaning2) (+/- 48 hours due to management related disturbances). The PostWean period consisted of the day of weaning (56 d) and 2 d after (total 3 d). Days were chosen to present balanced time points across each experimental period whilst best avoiding management disturbances such as cleaning of the barn and other procedures that we were unable to influence timings of due to working on a commercial farm.

6.3.6 Statistical analysis

Data from 11 kids were excluded because they died, were considered 'sick' (health score >3) or jumped into different pens, and one kid was removed due to error in the measurement of weight gain. Statistical analysis was performed in Minitab 18 (Minitab, 2019). ADG data from 163 female kids across six pens (55 AW; 52 GW1 and 56 from GW2) were analysed using General Linear Models (GLM) for each of the three experimental periods to generate estimated marginal means and determine the effects of weaning treatment on ADG data in each experimental period, these models included the 34-day weight as a covariate and treatment as a fixed factor. The Tukey's method of identifying outliers was used and found four; the analysis was run both with and without these outliers and as there was no difference on the significant effects of the treatment by using either method, the results were analysed and reported after exclusion of these four outliers (data from a total of 159 female kids). Model residuals were checked for normality using the Shapiro-Wilks statistic, and homogeneity of variance was assessed visually via scatter plot. One non-normal residual (Weaning1 ADG) was identified so the analysis was repeated after applying normalising and stabilising transformations; however, this did not alter the statistical significance and therefore as generating estimated marginal means was a key aim, results from the untransformed data are presented.

Kruskall-Wallis H tests were performed to test for differences in behavioural frequencies (Table 6-2) between the weaning treatments in each of the experiment periods, with pairwise comparisons made by Dunn's post hoc tests with a Bonferroni adjustment.

6.4 Results: Experiment 1 – gradual weaning under commercial conditions

6.4.1 On-farm feasibility

Whilst there was initial reluctance from farm staff to remove and replace the milk teats daily, they were able to select timings to fit in with their schedule of work and reported that this was a quick and feasible addition to their routine.

6.4.2 Weight gain

Body weight at weaning (56 days) (median ± IQR) was 14.0±2.90kg (AW), 14.6±3.45kg (GW1), and 13.2±2.98kg (GW), and at 60 days old (final study weight) body weights were 14.7±2.90kg (AW), 15.1±3.65kg (GW1) and 13.2±2.20kg (GW2). There were unclear effects of weaning treatment on ADG as when both weaning treatments were under the same protocol (3.5 h/d teat removals from 35-45 d: Weaning1), GW2 had significantly higher ADG, there were no differences during the differing weaning treatment period (45-56 d: Weaning2) and PostWeaning (56-60 d) AW kids had significantly higher ADG (Table 6-3). Kid weight as measured at 34 days of age significantly impacted all periods (Table 6-3).

Table 6-3. Results of General Linear Models of 159 female goat kids on three different weaning treatments for each of three experimental periods (Experiment 1).

Period	Factor	Abrupt	Gradual1	Gradual2	Treatment	34d weight
		EMM ± SE	EMM ± SE	EMM ± SE	*p* (F)	*p* (F)
Weaning1 (35-44 d)	ADG (g/ d)	0.15 ± 0.017	0.28 ± 0.017	0.15 ± 0.017	<0.001* (20.51)	0.003* (9.30)
Weaning2 (45-55 d)	ADG (g/ d)	0.19 ± 0.011	0.17 ± 0.011	0.20 ± 0.011	0.151 (1.91)	<0.001* (28.66)
PostWean (56-60 d)	ADG (g/ d)	0.13 ± 0.026	0.04 ± 0.026	0.07 ± 0.026	0.048* (3.10)	0.022* (5.38)

Abbreviations: EMM = Estimated Marginal Means; SE = Standard Error; ADG = Average Daily Gain.
* Indicates significant differences at the alpha value of <0.05 (5%)

6.4.3 Behaviour

No significant treatment differences were found in frequency of general play behaviour across all experimental periods, however significant differences were found in feeding competition during PreWeaning, feeding during Weaning, and frustrated suckling motivation PostWeaning (Table 6-4).

Table 6-4. Results of Kruskall-Wallis H tests (with pairwise comparisons made by Dunn's post hoc tests with a Bonferroni adjustment) comparing mean proportion of goat kids per pen performing the behaviour, summed across scans under three weaning treatments (Abrupt = 3 pens, Gradual 1 = 2 pens, Gradual2 = 2 pens) (Experiment 1).

Period	Behaviour	Abrupt	Gradual1	Gradual2	(χ2(2)	*p*
		Mean Rank Scores				
PreWean (14-34 d)	Feeding competition	116.45[a]	119.06[a]	149.01[b]	10.018	0.007*
	Frustrated suckling motivation	127.19	127.56	124.40	0.100	0.951
	General play	117.78	139.51	126.56	4.656	0.098
	Feeding	122.43	140.31	118.81	3.728	0.155
Weaning1 (35-44 d)	Feeding competition	68.01	57.39	62.85	2.137	0.344
	Frustrated suckling motivation	54.55[a]	68.43[a]	72.00[a]	6.354	0.042*
	General play	59.59	62.33	70.53	2.229	0.328
	Feeding	54.65[a]	58.36[a]	81.92[b]	13.043	0.001
Weaning2 (45-55 d)	Feeding competition	68.36	55.67	64.04	3.288	0.193
	Frustrated suckling motivation	57.77	64.15	71.44	3.186	0.203
	General play	58.70	69.26	64.93	2.964	0.227
	Feeding	66.07	58.32	64.82	1.040	0.595
PostWean (56-60 d)	Frustrated suckling motivation	71.88[a]	66.24[a]	48.19[b]	9.683	0.008*
	General play	65.62	59.24	64.58	2.716	0.257
	Feeding	65.51	59.03	64.96	0.761	0.684

Superscript indicates where significant differences occur between treatments.
* Indicates significant differences at the alpha value of <0.05 (5%)

6.5 Materials and methods: Experiment 2 – detailed feeding behaviour during gradual weaning under research conditions

Based on the results of Experiment 1 showing unclear weight gain results (as a weight gain difference was identified when the gradual weaning treatments were the same), but significant behavioural differences indicating that GW2 kids showed lower levels of frustrated

suckling motivation post weaning, GW2 was the gradual weaning method selected for further investigation.

6.5.1 Animals and housing

Male mixed dairy breed (Saanen, Alpine, Toggenburg) kids were collected from a single commercial dairy farm at three to seven days of age and taken to the rearing facility for the duration of the experiment (June to September 2021), comprising of livestock barn housing on a farm in Somerset, England. Due to practical and welfare restrictions regarding availability and transportation of young kids, only male kids could be sourced. Data from kids that were within the abrupt weaning treatment (Pens 2 and 4) were used for research that described ad libitum milk feeding behaviour and has been published (Vickery et al., 2023), all care protocols were the same other than milk removal for the gradual weaning pens. Four 3.66 x 3.66m (13.40m^2) pens fed with one milk teat per pen, connected to a Forster-Technik VARIO smart milk feeder were used. Kids were cared for according to standard industry practice, castrated via elastration at <7 days of age, bedded on straw and vaccinated with clostridial vaccinations (Heptavac P+) at three and seven weeks of age. Ad libitum creep feed (Mole Valley Farmers prime calf rearing nuts; 870g/kg dry matter (DM), 190g/kg crude protein CP)), barley straw (890g/kg DM, 30g/kg CP) and grass hay (890g/kg DM, 60g/kg CP) were provided ad libitum in raised feeding stations (base 500mm from floor; hay and straw feeders L:590mm W:430mm H:565mm; creep feeder L:590mm W:590mm H:580mm). Milk powder (Volac Blossom Hi-Spec 250g/kg CP) was mixed at 40 degrees Celsius at a rate for 150g/kg dry matter. Each morning the milk feeder components and feeding station were sterilised. One wooden cable spool per pen provided physical enrichment.

Upon arrival kids were kept within a 2.44 x 2.44m (5.95m^2) pen for five days and were assisted to find the milk feeding station and suckle four times per day. When the feeder recorded kids feeding themselves, help ceased for that individual; kids who had not learnt to reliably use the system by 14 days or who showed signs of ill health were removed from the experiment before it began (nine kids). Feed and water intake was monitored from 15 to 70 days of age, however due to some kids requiring milk feeding assistance between 15 and 20 days, and because incidences of two kids entering the feeding station at once were recorded, milk feeding data was not analysed until 22 days of age when all kids were feeding independently and could only fit into the station singularly.

6.5.2 Experimental design

There were two pens each of AW (nine kids each, weaned by sudden milk removal at 56 days of age) and GW2 (one pen of eight and one pen of nine kids, weaned gradually by

removing milk teats for periods of time each day), for full treatment details see Table 6-1. All kids had complete removal of access to milk at 17:00h at 56 days of age (according to standard UK practice:1,11) and post-weaning measurements continued until day 70.

6.5.3 Measuring milk intake and feeding behaviour

Feed stations specially fabricated from steel and lined with hygienic parlour board sheets (W:195mm, H:700mm, L:600mm, teat set at 450mm from floor) with a built in RFID reader (that identified each kid's individual ear tag) enabled milk intakes to be individually recorded. Teat suckling triggered a kidney dialysis pump and each turn of the pump dispensed 5ml of milk (calibration found accuracy to be within 5ml per 500ml). Monitoring occurred for 24 h/day; number, time, and duration of visits, and milk consumed was recorded. When the teats were removed during gradual weaning (by unscrewing them from the base, with no other changes made to the feeding station), visits to the feed station were monitored but kids were unable to consume milk.

6.5.4 Solid feed and water intake

Between 08:30 and 10:00h each day, creep feed, hay, straw, and water consumption were recorded on a pen level (daily feed/water intake = food/water given – food left from the day before). The water bucket was mounted to the wall to minimise spillage and if the bucket had been disturbed, data were not recorded for that day. The hay and straw feeders had a wider base to attempt to collect spilled feed which was collected and added to the leftover food weighed each day, however it was difficult to accurately account for all hay and straw dropped by the kids after taking a mouthful.

6.5.5 Weight gain

Enrolment weights were taken upon arrival, and kids were then weighed weekly, and on the last day of each experiment period, with the last weight recorded on day 70. Weights were used to calculate ADG for each of the experiment periods (PreWean (enrolment-35 d), Weaning1 (35-45 d), Weaning2 (45-56 d), and PostWean (56-70 d).

6.5.6 Health measures

Health observations were scored at every weighing session as per Experiment 1 (section 6.3.4). As recommended upon consultation with a veterinarian (due to the prevalence of cryptosporidium on dairy farms and the likelihood of an outbreak due to transportation stress and introduction to a new environment), all kids were put on a prophylactic course of

Halofuginone lactate upon arrival. Gradually weaned kids were visually monitored for signs of bloat 30min, 1h and 2h after milk teats were replaced after a period of removal.

6.5.7 Behavioural observations

The same CCTV system as in Experiment 1 was used and recorded for six h/d in three blocks (1000-1200; 1330-1530; 1630-1830) to capture milk teat removal and replacements. Due to equipment malfunction only two pens (pen 3 – GW2, and 4 -AW) were recorded for the Weaning1, Weaning2 and PostWean periods. Each of the two 10 d treatment periods (Weaning1 and Weaning2) were analysed at +3, 6 and 9 d (start date being average birth date +35 d for Weaning1 and +45 d for Weaning2). The PostWean period consisted of the day after weaning (57 d of age), +3, 6 and 9 d (total 4 d). As stated previously, days were selected for representativeness of each study period and to avoid days in which weighing, or personality tests were performed (for a concurrent study). All days selected were +/- 24 h due to CCTV technical issues. All kids were marked to enable individual identification and five-minute focal kid scan sampling was used to analyse the footage according to the behavioural ethogram (Table 6-2) with some modifications (touch teat area was not recorded; ‘push off teats’ changed to ‘attempt displacement’ – defined as ‘kid contacts the body of the kid that is inside the feed station’; ‘queueing’ was modified to ‘being within one body length of the feed station entrance whilst another kid is inside’; for ‘feeding’ behaviours ‘activity towards forage’ was split into hay and straw; and ‘activity towards water’ was added).

6.5.8 Missing data

Milk intake was monitored closely and if a kid had not consumed any milk by 10:00h, or if by 20:00h a kid was below 50% of the average individual milk consumption for its pen, they were placed inside the feeding station and encouraged to feed, and the individual’s milk feeding data was then excluded for that day. This resulted in six one-day removals of data for five kids. There was a further one-day removal of milk data for one kid due to an unknown recording error. Daily creep feed intake was not recorded on five days due to spillages; seven days of water intake were not recorded due to water spillages and data sheet damage.

6.5.9 Statistical analysis

Two kids died during Experiment 2 (one from AW due to pneumonia and one from GW2 was euthanised due to suspected urolithiasis) and their data was removed from all analysis, leaving a total of 33 kids. Analysis was conducted in Minitab 18 (Minitab, 2019). GLMs were used to test for significant differences between the outcome variable (ADG or milk intake) and included the PreWean value as a covariate and treatment as a fixed factors, for each of the

three remaining experimental periods. Residuals were tested for normality using the Shapiro-Wilks procedure and homogeneity of variance was assessed visually via scatter plots; all models met the assumptions. Mann-Whitney U tests were performed to test for differences in feed and water intakes between the weaning treatments in each of the Experiment periods.

Estimated marginal means of milk intake produced by the GLMs were used to calculate milk powder costs during the weaning periods for each treatment. Pen level creep feed intakes were used to give estimates of creep feed costs; where daily intake data was missing an average of the 2 days prior and 2 days after the missing day was used. The manufacturer recommended retail price of each input at the time of the experiment (September 2021: £9.65/25kg creep feed, £2250/1000kg milk powder) were used to calculate costs. As hay and straw retail costs are highly variable and represent only a small proportion of total rearing costs (<£1 per kid), these were not included in the cost analyses. Two one-way ANOVAs were performed to compare the effect of weaning treatment on 70-day body weights, and on milk cost calculated from day 35 to 56 (Weaning1 and Weaning2 periods).

Behavioural analysis was conducted using Mann-Whitney U tests (with each behaviour variable presented as sum incidences divided by the number of days observed in the period) to identify if there were differences in behavioural expression between the weaning treatments in each of the experiment periods.

6.6 Results: Experiment 2 – detailed feeding behaviour and gradual weaning under research conditions

6.6.1 Weight gain and milk intake

Body weight at weaning (56 days) (median ± IQR) was 14.6±3.84kg AW kids, and 15.3±1.85kg for GW kids, at 70 days old (final study weight) body weights were 17.3±2.74kg (AW) and 18.4±2.20kg. A one-way ANOVA found no statistically significant difference in 70-day weights between AW and GW2 kids ($F(1, 31) = 1.2939$, $p = 0.2641$).There were no statistically significant effects of weaning treatment on ADG or milk intake during the first weaning period (35-44 d: Weaning1); however, during the second weaning period (45-55 d) GW2 kids had higher ADG and lower milk intakes (Table 6-5). ADG results postweaning were not statistically significant but trended towards GW2 kids having higher ADG (Table 6-5).

Table 6-5. Results of General Linear Models of 33 goat kids on two different weaning treatments for each of three experimental periods (Experiment 2).

Period	Factor	Abrupt (AW)	Gradual2 (GW2)	Treatment	PreWean
		EMM ± SE	EMM ± SE	*p* (F)	*p* (F)
Weaning1 (35-44 d)	ADG (g/ d)	0.22 ± 0.014	0.22 ± 0.013	0.772 (0.09)	0.026* (5.52)
	MI (ml/ d)	2199 ± 54.2	2079 ± 52.5	0.136 (2.35)	<0.001* (54.08)
Weaning2 (45-55 d)	ADG (g/ d)	0.21 ± 0.013	0.25 ± 0.013	0.046* (4.34)	0.295 (1.14)
	MI (ml/ d)	2294 ± 102.0	1962 ± 98.5	0.032* (5.09)	<0.001* (22.46)
PostWean (56-70 d)	ADG (g/ d)	0.19 ± 0.010	0.21 ± 0.010	0.074 (3.42)	0.970 (<0.001)

Abbreviations: EMM = Estimated Marginal Means; SE = Standard Error; ADG = Average Daily Gain; MI = Milk Intake.
* indicates significant differences at the alpha value of <0.05 (5%)

6.6.2 Milk feeding behaviour

Milk intake per hour was graphed to look for rebound effects of teat removal and replacement that could cause higher levels of milk intake once the teats are replaced (compensatory feeding), and Figure 6-1 shows that this was not observed.

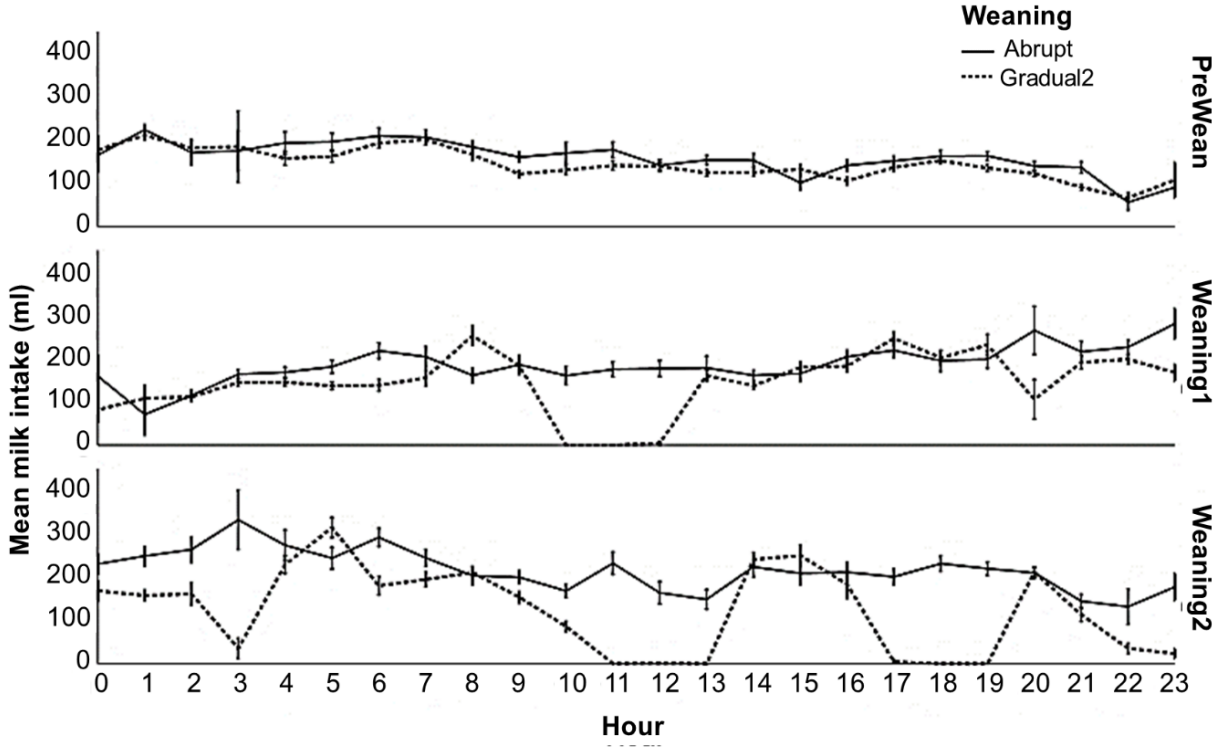

Figure 6-1. Milk intake by hour during the experiment periods of 33 goat kids reared on artificial milk supply systems on two weaning schedules (Error bars +/- 1SE) (Experiment 2).

Furthermore, no incidences of bloat were recorded for any kids throughout Experiment 2. Visits to the feeding station post weaning decreased rapidly for both abruptly and gradually weaned kids; from 17:00 to 00:00h on d 56 (the period immediately following weaning) AW kids visited the feeding station 110 times ± 3.9, whereas GW2 kids recorded 77 ± 3.2 visits, on d 57 GW2 kids visited fewer times than AW kids, but on d 58 they had slightly more visits (Figure 6-2).

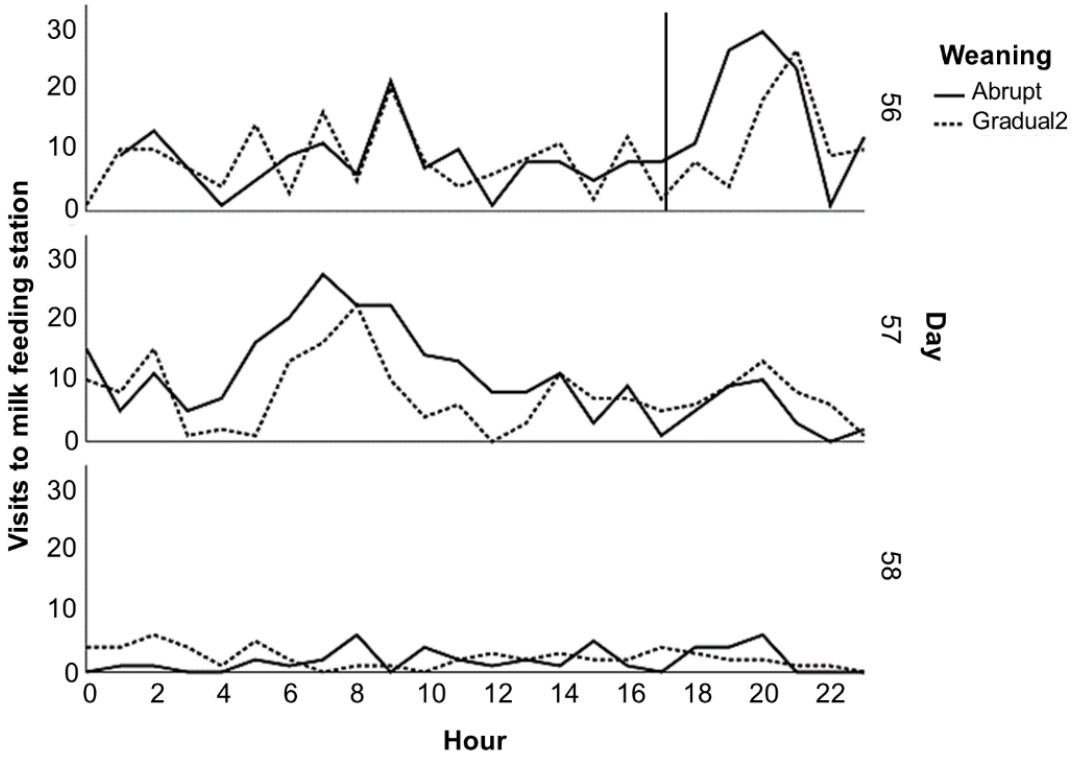

Figure 6-2. Visits to the milk feeding station per hour post weaning (time of weaning indicated by a solid marker line – 17:00 on day 56) of 33 goat kids reared on artificial milk supply systems on two weaning schedules (Experiment 2).

6.6.3 Solid feed and water intakes

Pen-level solid feed and water intakes are displayed in Table 6-6 and show that there were significant differences between the abrupt and gradually weaned kids at multiple points during the experiment.

Table 6-6. Results of Mann-Whitney U tests comparing creep (g/ d), hay (g/ d), straw (g/ d) and water (ml/ d) intakes per kid (all available ad libitum) of goat kids reared on artificial milk supply systems on two weaning treatments (Experiment 2). Feed intake data was collected on the pen

level (n = 2 Abrupt, 2 Gradual2) then divided by the number of kids in the pen to present an approximate per kid intake value.

Period	Intake	Abrupt	Gradual2	U	*p*
		Mean ± SE	Mean ± SE		
PreWean (14-34 d)	Creep	13 ± 1.6	8 ± 1.0	556.5	0.042*
	Hay	17 ± 1.4	14 ± 1.2	652.0	0.154
	Straw	27 ± 2.3	18 ± 1.8	497.5	0.004*
	Water	80 ± 7.8	73 ± 6.2	770.0	0.773
Weaning1 (35-44 d)	Creep	24 ± 2.0	51 ± 8.9	122.0	0.022*
	Hay	58 ± 5.2	38 ± 4.7	125.5	0.006*
	Straw	46 ± 2.0	35 ± 2.1	93.5	<0.001*
	Water	112 ± 14.6	161 ± 23.3	176.5	0.185
Weaning2 (45-55 d)	Creep	58 ± 3.7	182 ± 13.1	1.0	<0.001*
	Hay	92 ± 3.9	118 ± 6.2	108.5	0.002*
	Straw	68 ± 4.8	49 ± 3.5	108.5	0.002*
	Water	109 ± 32.9	103 ± 18.6	174.0	0.242
PostWean (56-70 d)	Creep	557 ± 38.7	663 ± 29.4	59.0	0.073
	Hay	189 ± 8.3	149 ± 5.3	18.0	<0.001*
	Straw	127 ± 8.9	92 ± 8.6	32.5	0.002*
	Water	1376 ± 53.2	1485 ± 78.0	29.0	0.013*

* Indicates significant differences at the alpha value of <0.05 (5%)

6.6.4 Rearing costs

During the two weaning periods, GW2 kids had slightly lower milk powder but higher creep feed costs than AW, however overall, there was little difference in total rearing costs between the treatment groups (Table 6-7). A one-way ANOVA found no statistically significant difference in milk powder costs between AW and GW2 kids ($F(1, 31) = 0.0182$, $p = 0.8936$).

Table 6-7. Approximate rearing costs per kid for each experimental period of goat kids abruptly or gradually weaned from an artificial milk supply system (Experiment 2). Estimates calculated in September 2021.

Period		Abrupt	Gradual2
	Milk intake/kid/period (ml)	21990	20790
Weaning1	Milk cost (£)	12.86	12.16
(35-44 d)	Creep intake/kid/period (g)	256	549
	Creep cost (£)	0.12	0.26
	Milk intake/kid/period (ml)	22940	19620
Weaning2	Milk cost (£)	13.42	11.48
(45-55 d)	Creep intake/kid/period (g)	640	1997
	Creep cost (£)	0.31	0.96
PostWean	Creep intake/kid/period (g)	7798	9284
(56-70 d)	Creep cost (£)	3.76	4.48
	Total cost (£)	30.48	29.35
	Median ± IQR 10wk kid body weight (kg)	17.30±3.74	18.35±2.20
	Cost per kg of bodyweight (£)	1.76	1.61

6.6.5 Behaviour

There were not enough incidences of behaviours indicative of feeding competition ('queue for feed station access' and 'attempt displacement') to include in analysis. Table 6-8 shows that during Weaning1, GW2 kids had higher levels of activity towards water, and lower levels of activity towards hay. During Weaning2 GW2 kids showed lower levels of play, whereas in the PostWean period this reversed, with GW2 kids showing higher levels of play (with zero incidences of play observed for AW kids) and higher activity towards water, but lower levels of activity towards straw.

Table 6-8. Results of Mann-Whitney U tests comparing the mean behaviour frequencies during daily scan sampling of 33 goat kids housed in four pens (2 Abrupt, 2 Gradual) reared on artificial milk supply systems on two weaning treatments (Experiment 2).

Period	Behaviour	Abrupt	Gradual2	U	*p*
		Mean ± SE	Mean ± SE		
Weaning1 (35-44d)	General play	0.41 ± 0.155	0.48 ± 0.113	35.50	0.648
	Activity towards water	0.15 ± 0.081	1.00 ± 0.278	16.00	0.023*
	Activity towards hay	3.89 ± 0.364	1.56 ± 0.236	2.50	0.001*
	Activity towards straw	1.15 ± 0.273	1.45 ± 0.215	30.00	0.338
	Activity towards creep	0.44 ± 0.136	0.96 ± 0.204	19.50	0.059
	Frustrated suckling motivation	0.15 ± 0.081	0.07 ± 0.074	32.50	0.331
Weaning2 (45-55d)	General play	0.41 ± 0.134	0.07 ± 0.049	19.50	0.039*
	Activity towards water	0.00	0.00	na	na
	Activity towards hay	3.96 ± 0.602	2.96 ± 0.349	24.00	0.143
	Activity towards straw	2.15 ± 0.390	2.59 ± 0.411	30.00	0.349
	Activity towards creep	1.56 ± 0.319	1.67 ± 0.434	39.50	0.929
	Frustrated suckling motivation	0.07 ± 0.049	0.30 ± 0.188	34.00	0.466
PostWean (56-70d)	General play	0.00	0.81 ± 0.212	0.00	<0.001*
	Activity towards water	0.56 ± 0.185	1.64 ± 0.280	11.50	0.010*
	Activity towards hay	5.53 ± 0.961	3.64 ± 0.354	24.00	0.144
	Activity towards straw	7.56 ± 1.129	4.72 ± 0.558	18.00	0.047*
	Activity towards creep	4.75 ± 0.579	6.53 ± 0.880	20.50	0.076
	Frustrated suckling motivation	0.22 ± 0.106	0.19 ± 0.091	38.00	0.810

* Indicates significant differences at the alpha value of <0.05 (5%)

6.7 Discussion

Weaning goat kids gradually by removing milk teats at pen-level was feasible for use on-farm. However, weight gain results recorded from a commercial farm in Experiment 1 were mixed, as during the first weaning period when there were no differences in milk removal timings, GW1 kids (long period milk removal in the second weaning phase) showed the highest weight gains but over four days postweaning abruptly weaned kids had the highest gains; however this short period is unlikely to be representative of long-term weight gain (Experiment 1). Furthermore, kids in this study showed behavioural differences preweaning when no treatment differences had been imposed: GW2 kids (split-period milk removal in the second phase) displayed higher levels of feeding competition before weaning and higher durations feeding on solids during the first weaning period), making interpretation of treatment differences difficult. Postweaning, GW2 displayed lower levels of 'frustrated suckling motivation' (Experiment 1). However, it should be noted that behavioural analysis could not be recorded on the individual level, which is a limitation as inter-individual behavioural differences are apparent in goat kids ((Finkemeier et al., 2019; Toinon et al., 2021) which likely impacts their coping ability (Çakmakçı et al., 2021; Toinon et al., 2021) and productivity (Neave et al., 2018).

Experiment 2 was able to explore feeding behaviour in more detail, however results should be interpreted with caution due to the limited sample size, small number of pen

replicates, and study of male kids. Some research suggests that male kids grow faster than females (Davis et al., 1998; Rojo-Rubio et al., 2016), which means growth results are not directly comparable between our experiments; however, the male kids were castrated due to practical requirements and therefore show lower growth rates than entire males (Louca et al., 1977; Murray et al., 2001) and other work has found no impact of sex on weight gain in kids studied up until 28 days old (Delgado-Pertíñez et al., 2009). When compared to abrupt weaning, GW2 kids had higher growth rates during the second weaning period and a trend towards higher ADG over a longer post weaning period (56-70 days rather than 56-60 days in experiment 1) alongside lower milk intakes during both weaning periods. Pen-level solid feed intakes showed differing results dependant on feed type, however, GW2 kids had higher creep intakes during weaning and higher water intakes postweaning. Behavioural observations showed that during the second weaning period GW2 kids displayed lower levels of play, whereas postweaning this reversed – with GW2 kids showing higher levels of play (zero incidences of play were observed for AW kids).

Whilst results varied between the two experiments, which likely reflects differing conditions and difficulties around reproducibility with animal data, collecting data from commercial and research conditions allows for a well-rounded initial understanding of the weaning transition and implications for kid management in the 'real world'. Experiment 2's more controlled conditions found that ADG trends towards being higher in gradually weaned kids post weaning is in agreement with calf literature demonstrating that gradual weaning minimizes or prevents a growth rate reduction at weaning (Khan et al., 2007; Sweeney et al., 2010) and increases solid feed intake (Khan et al., 2007). In terms of goat kid literature, our growth findings differ to those of Zobel et al. (Zobel et al., 2019) who considered abrupt, step-down volume and step-down dilution weaning groups likely due to the older age at which weaning occurred, and with Magistrelli et al. (2013) who found no negative effect on weight gain, behaviour or physiological parameters for kids weaned by step-down volume (however these results must be interpreted with caution due to a lack of abrupt weaning control group and sample of only 11 animals). Our research implemented a longer gradual weaning stage (20 days) compared to Zobel et al. (Zobel et al., 2019)'s six-day period from 57-63 days of age, but was comparable to Magistrelli et al. (Magistrelli et al., 2013)'s 19-day period from 29-48 days of age. The difference between the present experiments in terms of growth findings could relate to the second study's longer 14-day period of following kids post-weaning, which is more likely to be indicative of true weight gain; furthermore, the differences in social dynamics (Experiment 1 had pens of 25-32 kids versus 7-9 in experiment 2) could have impacted feeding competition which may explain some growth rate differences.

Compensatory growth is a physiological process whereby an animal increases its growth rate following a period of reduced feed intake, to ‘catch up’ with animals that never experienced a reduction (Hornick et al., 2000), and is frequently seen in juvenile animals (Ryan, 1990) including eight-month-old goat kids (Dashtizadeh et al., 2008). This could be an important consideration for post-weaning growth, however, in cattle and sheep there appears to be a period from birth to three months of age when restriction does not trigger compensatory growth (Ryan, 1990) this has not been investigated in goats younger than eight months. Following kids for longer post weaning would be valuable when assessing the impacts of gradual weaning on post weaning differences and possible compensatory growth. The four-day period postweaning for Experiment 1 is unlikely to accurately reflect weight gain and could be influenced by gut fill or compensatory solid feeding, however this follow-up was limited due to the commercial conditions and kids being rehoused. It would be further beneficial to track female kids to their first service and lactation to understand possible links with future productivity.

Weaning in young ruminants involves the transition from mono-gastric digestion of milk in the abomasum to digestion of solid feedstuff with microbial fermentation in the rumen (Huber et al., 1969) and the physiological events required have been described as a dramatic challenge (Baldwin et al., 2004). Rumen development is affected by pre-weaning consumption of solid feedstuff (Nocek et al., 1980) and in goat kids, solid feed intake has been positively correlated with the weight of the reticulo-rumen (Hamada et al., 1976) and in lambs rumen development is improved by a gradual weaning schedule (Carballo et al., 2019). Calf research suggests that pre-weaning high milk intakes can cause issues after abrupt weaning including decreased solid feed intake (Weary et al., 2008) and reduced weight gain linked to slower rumen development (Khan et al., 2007; Sweeney et al., 2010). Solid feed intake and consequent rumen development is critical to successful weaning, so considering factors that affect the intake of solid feed is important. Experiment 1 was limited by an inability to collect feed intake data; although feeding behaviour observed via CCTV was used as a proxy and one weaning group had higher levels during the first weaning period, this difference was not observed during the second weaning period or post weaning. Non-invasive measures of rumen development are limited and therefore we were unable to investigate physiological markers during weaning for either experiment.

Whilst higher levels of solid feeding behaviour may have been a response to teat removal, both gradual weaning groups had the same teat removal timings during the first weaning period and therefore should not have showed differences. The group showing higher feeding behaviour in Experiment 1 also had a significant pre-weaning behavioural difference (higher levels of feeding competition), which may have been a confounding factor for this group of kids and could reflect differing social dynamics within the pen. Increased levels of feeding

competition result in larger variability in weight gains in pigs, with the smaller animals showing the lowest growth rates (Georgsson and Svendsen, 2002). In calves, increased competitive interactions results in decreased feeding time and milk intake (von Keyserlingk et al., 2004). Due to practical constraints, Experiment 2 was only able to evaluate one method of gradual weaning in greater detail and therefore as differences in weight gain were unclear, the weaning treatment which showed significantly lower levels of frustrated suckling motivation postweaning (GW2) was selected.

During Experiment 2 feeding behaviour was investigated in greater detail for abrupt weaning and gradual weaning with a split period teat removal (GW2), however solid feed and water intakes could only be recorded at the pen level so must be interpreted with some caution. Results show that preweaning (no treatment differences) abruptly weaned kids were consuming higher levels of straw and creep feed. The difference in straw consumption remained, with the abrupt weaning pens consuming more straw across all periods, suggesting that group differences may exist due to individual feeding preferences and perhaps a degree of social contagion of feeding behaviour. However, the difference in creep intakes reversed with the gradually weaned kids showing higher creep feed intakes during both gradual weaning periods, and whilst not significant, the PostWean intakes trended towards a higher mean value. As creep intake is critical to rumen development and successful weaning (Calves, Coverdale et al. (Coverdale et al., 2004)), and higher creep feed intakes result in improved rumen morphology (goat kids, Htoo et al. (Htoo et al., 2018)), this finding is of particular interest to farms weaning their kids at a young age when they may not have started ingesting significant amounts of solid feed. The gradually weaned kids also showed a significantly higher level of water intake postweaning. Whilst creep feed intakes were higher for the gradually weaned kids during the weaning periods, the opposite was true for straw consumption, and hay intakes varied across treatments. There is little literature to aid our interpretation of this difference and the relationship between forage consumption and weaning treatment is unclear.

Milk intakes were recorded on an individual level during Experiment 2 and results suggest that gradually weaned kids decrease their milk intakes over the gradual weaning period whilst milk teats are removed, which coincides with an increase in solid feed intakes and an increased ADG. Milk intakes during gradual weaning have not been evaluated for goat kids before and our results suggest that this is a promising on-farm strategy. With the RFID technology utilised to record milk intake, visits to the feeding station post weaning were also recorded and showed that in the acute post weaning period (48 hours after milk removal) the abruptly weaned kids visited the milk feeding station more frequently, suggesting that gradually weaned kids had habituated to milk access being removed whereas the abruptly weaned kids had never experienced this before and likely experienced higher levels of stress as a result.

Age was chosen as the weaning criterion as whilst weight is a lower risk strategy (Lu and Potchoiba, 1988) age is more commonly used by farmers (Anzuino et al., 2019; Vickery et al., 2022a). The increasing costs of inputs, particularly milk powder drives the desire to wean earlier, therefore, if gradual weaning decreases milk replacer intakes whilst increasing solid feed it could improve outcomes for both kids and farmers. Recording individual milk intakes and pen-level creep intakes during Experiment 2 allowed for rearing costs to be approximated for each weaning treatment, and a small difference was seen (gradually weaned kids cost on average £1.13 less); showing that increased creep feed intakes of gradually weaned kids were financially compensated for by the lower milk intakes, which is more expensive per gram. In a recent survey of goat kid rearers (Vickery et al., 2022, feasibility and rearing costs were of key concern, and this research provides evidence to suggest making simple management changes like introducing gradual weaning via pen-level teat removal to improve welfare would be feasible and not affect rearing costs.

The age at which gradual weaning begins is an important consideration, as very early implementation results in calves being unable to cope with the reduced nutrients from milk intake (Sweeney et al., 2010). However, ‘successful’ weaning of goat kids (as measured by growth and mortality, without consideration of behavioural effects) has been documented as young as 45 (Ugur et al., 2007) and 35 days of age providing they were consuming >30 grams of solid feed daily (Lu and Potchoiba, 1988). It has been demonstrated that lambs can be weaned as early as four weeks without detrimental effects on growth or organ development (measured at 16 weeks: 40) providing that milk allowance was stepped down to encourage solid feed intakes. However, other studies have shown that the youngest weaned lambs (6 weeks, compared to 13 and 21 weeks) were the most behaviourally ‘agitated’ (Schichowski et al., 2010). In our first experiment we observed lower levels of behaviours indicative of ‘frustrated suckling motivation’ within the GW2 group however this difference was not observed in the second experiment. In the second experiment GW2 kids showed lower levels of play in the second weaning period, perhaps indicative of their response to reduced milk availability, this was reversed in the Post Wean period when GW2 kids had higher levels of play behaviours which could indicate improved welfare, particularly as no play was observed in AW kids. It has been proposed that the absence of play is a reliable indicator of a change from positive to poorer welfare (Held and Špinka, 2011), as it is a ‘luxury’ behaviour that decreases when energy resources are limited, or the activity cost increases (McFarland, 1993).

6.8 Conclusions

The results of the research presented here collected from experiments conducted under commercial and research conditions indicate that implementing a gradual weaning programme

from 35 days of age may have a positive effect on goat kids' performance, as measured by ADG, and was suggestive of positive effects on kid behaviour and therefore their overall welfare. Our work demonstrates that 3.5-hour block teat removals did not increase feeding competition or cause compensatory milk feeding (in fact milk intakes reduced during weaning which could be economically beneficial to farmers) but did increase creep feed intake. Lower levels of behaviours indicative of frustrated suckling motivation, higher levels of post weaning play behaviours, and fewer post weaning visits to the feed station suggest that gradually weaned kids were better psychologically prepared for full milk removal. However, it would be beneficial for future experimental work to investigate the optimal balance of milk access (including when to start gradual weaning, how long the weaning period should be, and for how long teats should be removed) to ensure good growth, increased solid feed consumptions and psychological preparation whilst avoiding detrimental impacts associated with limiting milk supply. Overall, results suggest that pen-level gradual weaning is feasible and can be recommended for implementation on commercial farms and that there is little difference in the costs incurred as a result; however further work to optimise protocols is recommended.

6.9 Ethics Statement

Ethical approval was granted by the University of Reading, School of Agriculture, Policy and Development, ref. 001028P (first experiment) ref. 001561 (second experiment) and Dalhousie University, ref. 2021-010 (second experiment).

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7. Evaluating the consistency of dairy goat kids' responses to two methods of assessing fearfulness

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7.1 Abstract

Evidence suggests that understanding individual behavioural differences could enhance welfare research. Many methods for assessing fear to make inferences about 'personality' have been proposed but not validated for goat kids. The study aimed to 1) assess interobserver reliability, 2) investigate individual-level test-retest reliability of Novel Object (NO) and Familiar Person (FP) tests; 3) establish the effects of testing environment (Modified Home (MH) or Unfamiliar Testing (UT) arenas) and weaning method (Gradually by increasing periods of milk access removal from a pen average of 35 days old until full milk removal at a pen average of 56 days(GW; n=18) or Abruptly by complete and sudden milk removal access at a pen average of 56 days old (AW; n=17)), and 4) test for associations between repeatable behaviours and production metrics. One AW pen and one GW pen were used for each testing environment (MH/UT). Four NO tests occurred, two pre-weaning (25d and 29d), and two post-weaning (63d and 67d); a FP test occurred the day after each. Tests lasted 180s (+90s habituation for NO tests) and were recorded. An observer blinded to weaning treatment scored all videos, and another scored 1 kid's test for each timepoint/pen. One kid from MH and 11 kids from UT environments were removed from testing early due to distress. Kendall's test of concordance indicated good interobserver reliability ($W1=0.670$, $p<0.001$). For FP tests 'bipedal stance' ($W3=0.379$ $p<0.001$) and 'stand still-look' ($W3=0.378$ $p=0.010$) and for NO tests bipedal stance ($W3=0.234$ $p=0.006$) and 'latency until contact' $W3=0.202$ $p=<0.001$ showed good test-retest repeatability. MH and UT environments were compared using Kendall's W (calculated for each behaviour separately), the coefficients were compared with Mann-Whitney U tests, which found no impact of testing environment ($p=0.579$). GLMMs assessed the effect of external factors pen, test type, and weaning treatment; concordance coefficients between individual kids' tests were the dependent variable with test type, kid age and pen as independent variables. The model of best fit was selected on the basis of lowest Akaike Information Criterion (AIC); test type ($p=0.184$) did not predict individual consistency, but pen did ($p=0.002$). Further GLMMs found no effect ($p>0.05$) of 'personality' indicators on weight gain, milk intake/day, nor relationship with weaning treatment, but a significant effect of bipedal stance on milk feeds/day ($p=0.04$) was identified. Results indicate that 'bipedal stance' in both tests, 'stand still-look' in FP tests, and 'latency to interact' in NO tests have good interobserver reliability and repeatability, therefore could be 'personality' indicators. Testing environment did not affect fear of kids that completed their tests, but that in practice the unfamiliar environment resulted in more distress-related removals therefore a modified home pen is recommended.

7.2 Introduction

Within farm animal research the individual is often under-considered in favour of group and pen level approaches (Fraser, 2009), despite this, the concept of animal welfare is defined as ‘a measurable quality of living at a specific time for an individual animal’ (Broom, 2011). Approaches that consider individuality are being increasingly promoted across farm animal welfare literature (Richter and Hintze, 2019; Winckler, 2019). Individuality in behavioural responses of goat kids was reported as early as 1988 (Lyons, 1989), but only recently has the idea that this individuality can be related to consistent ‘personality’ traits begun to be explored in goats. Further understanding of farm animal personality could help select individuals that can be housed in captivity with a lower likelihood of developing welfare problems (Richter and Hintze, 2019).

Fear and its behavioural indicators have been more commonly assessed in the welfare literature without repeated testing to attempt to assess it as a personality trait, and fear is deemed to be of welfare concern due to its experiential negative affective state (Boissy, 1995). This is of particular importance for animals farmed under commercial conditions which require them to adapt to, and cope with, conditions that they did not evolve within (Broom, 2011; Finkemeier et al., 2018), and is of commercial interest due to the heritability of traits such as reactivity and fearfulness (reviewed by Boissy et al., 2005) with links to productivity (Hemsworth et al., 2000). Individuals differ in the level of fear they display in response to a stressor, with more fearful individuals showing stronger behavioural responses (Boissy and Bouissou, 1995), and often decreased productivity (as reviewed in relation to human-animal relationships: Acharya et al., 2022). We are particularly concerned by fear if it is long-lasting or particularly intense, as whilst fleeting, short-lived fear expressed at a level appropriate to a specific stimulus is adaptive, longer lasting or intense fearfulness is maladaptive, particularly in farm environments, and contributes towards stress and an overall impaired welfare state. Therefore, the consistency, and intensity, of fear when measured over time is of interest, and ‘absence of general fear’ is a heading under the animal welfare principle ‘appropriate behaviour’ as laid out by the well validated assessment protocols ‘Welfare quality’ (Botreau et al., 2009).

Presently, fearfulness is typically assessed through response to novelty by utilising novel object tests (e.g., in juvenile goats, Finkemeier et al., 2022; Toinon et al., 2021), and response to humans (e.g., in calves, Bokkers et al., 2009; Meagher et al., 2016) however these tests have been criticised for their limited validation, unclear reliability, and inconsistent methodology x(Forkman et al., 2007) that make it difficult to generalise results. Indeed, whilst studies (Chojnacki et al., 2014; Toinon et al., 2021; Winblad von Walter et al., 2021) have assessed the reaction of goat kids to similar tests neither looked at the interobserver reliability or test-retest repeatabilities as these did not relate to their specific aims. Evidence shows that there are high

variations between goat kids in terms of their early growth rates (Deeming et al., 2016), and evidence from calves has found that more active and exploratory individuals consume intakes of solid feed earlier than other calves and have better growth rates (Neave et al., 2018). Whilst there are likely numerous factors that contribute to growth rate differences, individuality or personality has not yet been considered in goat kids. Individuals display a varying ability to cope with stressors and subsequently their likelihood of developing welfare issues differs (Koolhaas et al., 2010), therefore research that aims to understand reliable ways to assess goat kid behavioural responses, and if these meet the criteria to be classified as personality traits, could help us understand other aspects of kids' ability to thrive within commercial conditions.

The term 'personality' should only be used when individuals show differences in their behavioural responses that are consistent both temporally and contextually (Kaiser and Müller, 2021; Stamps and Groothuis, 2010). Whilst in goats there has been some work on personality, this has generally focused on adults with very specific research objectives: it has been demonstrated that adult goats do show stable personality traits that impact other variables (Finkemeier et al., 2022 personality trait boldness affected reversal learning performance: Nawroth et al., 2017 personality trait sociability affected visual discrimination). Only one study with kids has reported results from repeated tests that could meet the criteria for personality and found that 61% of 108 goat kids displayed consistent boldness and activity personality traits which were correlated with heart rate variability and weight gain (Finkemeier et al., 2019).

Understanding what traits contribute towards individual variability, and are affected by individuality, may help us to understand how to mitigate the stress of commercial management practices. This seems particularly relevant during the milk feeding stage and weaning transition when goat kids are expected to cope with a combination of stressors including separation from their dams, introduction to a new social and physical environment, and the transition from milk to solid feed without experienced social models. Therefore, the aims of the current study were to: 1) assess interobserver reliability, 2) investigate individual level test-retest reliability of Novel Object (NO) and Familiar Person (FP) tests; 3) establish the effects of two external factors: testing environment (Modified Home (MH) or Unfamiliar Testing (UT) arenas) to attempt to identify one to recommend for use in further research, and as the study animals were in two different weaning treatments for a concurrent study, abrupt and gradual weaning methods, 4) test for associations between repeatable behaviours that could be personality indicators and production metrics.

7.3 Materials and Methods

The research presented in this paper was granted ethical approval by the University of Reading, School of Agriculture, Policy and Development (ref. 001561) and Dalhousie University

(ref. 2021-010). The goat kids were cared for in accordance with the Department for Environment, Food and Rural Affairs code of recommendations for goats (2013) and the research occurred between June and September 2021.

7.3.1 Animals and housing

The male dairy cross-bred (Saneen, Toggenburg, Alpine) goat kids were used in a concurrent study to describe their feeding behaviour (Vickery et al 2023a) and compare gradual and abrupt methods of weaning (Vickery et al., 2023b); further detail regarding this experimental design is available in Vickery et al. (2023b). Briefly, 35 goat kids were divided into an Abrupt Weaning treatment (two pens of 8 and 9 kids; AW) that had ad libitum access to milk until complete removal at 17:00 hrs on d 56, and Gradual Weaning group (two pens of 9 kids; GW) that had ad libitum milk until 35 d when milk access was removed for 3.5hrs/d, at 45 d milk was removed for 7hrs/d, and then full milk removal occurred at 17:00 hrs on d 56.

All kids were cared for according to standard commercial management; bedded on straw topped up daily, castrated via elastration at <7 days of age, vaccinated with clostridial vaccinations at d 21 and 49, and had ad libitum access to straw, hay, creep feed and water from d 14. Individual level milk feeding data was recorded from day 22 to 56 days of age by a computerised milk feeder (Foerster-Technik VARIO smart) supplying one teat per pen, from 56 to 60 days of age (the immediate post weaning period) the kids visits to the milk feeding station continued to be monitored. Average Daily Gain (ADG) was calculated based on weekly weighing sessions.

7.3.2 For all testing

One AW pen and one GW pen was used for data collection for each type of testing arena (see Figure 7.1 for a detailed diagram of the layout of home pens and testing arenas). An external webcam was used to record the tests onto a laptop and the video files were then backed up onto external hard drives. Testing occurred between 15:30 and 19:30hrs. Any kids that exhibited extreme stress behaviours, combining distress vocalizations with more than two escape attempts (jumping into the walls of the test pen) had the test ended and the kid was immediately returned to the home pen.

Novel Object (NO) test

The novel objects used were four similarly sized but differently coloured and shaped plastic dog toys that were disinfected after each use. The kids were tested at age 25 d (yellow frisbee), 29 d (green tube), 63 d (orange wishbone), and 67 d (pink snake). After 90 s of

habituation time the novel object was placed inside the pen via a hole cut in the 1.22 m end of the testing corridor, and the test then took place for 180 s.

Familiar Person (FP) test

Kids were tested for their response to a familiar person the day following each of the novel object tests. One kid was released into the testing corridor where a stationary, familiar person (HMV – their daily caregiver) was stood wearing standardised clothing (green overalls) with a neutral expression looking straight ahead at the far end of the corridor (2.44m away). After 180 s the test ended, and the kids were returned to the group pen.

7.3.3 Experimental design – Environment 1: Modified Home (MH) pen test

Pens one (GW nine kids) and two (AW eight kids) were used, two 2.44m sheeted hurdles were carried into the kids standard 3.66 x 3.66 m home pen one hour before testing began. These sheeted hurdles created an L shaped test arena, for the hour before testing one side was left open so that the kids could familiarise themselves with the testing area. Once the habituation time ended one side of the hurdles was blocked to create a rectangular 2.44x1.22m corridor. One kid at a time was then lifted over the hurdle into the test pen (a modified familiar environment), leaving eleven kids in the 2.44 x 2.44 m pen whilst testing occurred. Kids could hear their pen mates and were also able to perform a bipedal stance against the hurdles and see their pen mates (Figure 7-1).

7.3.4 Experimental design – Environment 2: Unfamiliar Testing (UT) arena

Pens three (GW) and four (AW) were used and had nine kids per pen. A 2.44x1.22 m corridor was created within the same livestock barn as the goat kids but outside of their home pens (Figure 7-1). The corridor was created using 1.22 m tall white hygienic plastic sheets commercially known as ‘parlour board’ that the kids were unable to see over, but they could hear the goat kids in the same barn (Figure 7-1).

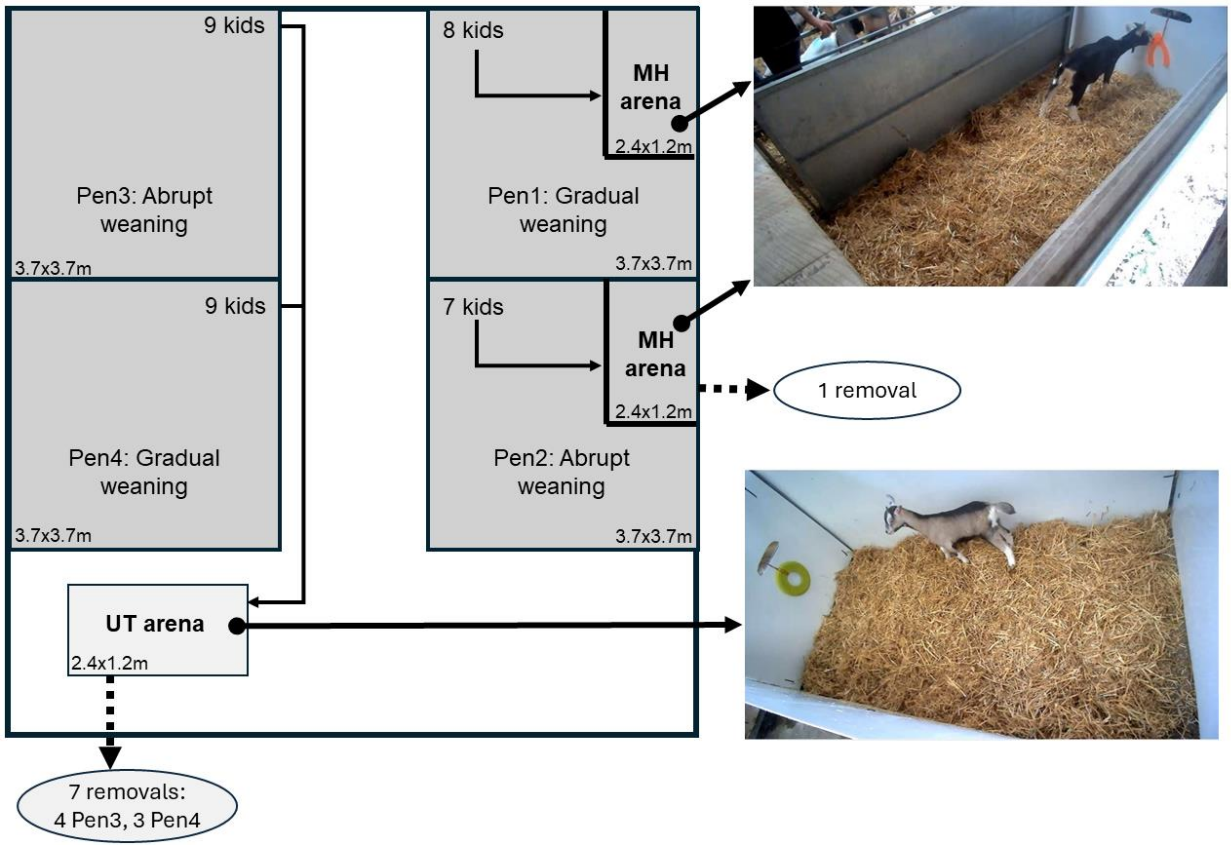

Figure 7-1. Diagram of the layout of the study barn and testing arenas with arrows indicating kid testing location and removals. UT = Unfamiliar testing; MH = Modified home pen.

7.3.5 Behavioural analysis

The ethogram (Table 7-1) was developed based on pre-existing literature (Neave et al., 2018; Toinon et al., 2021; Winblad von Walter et al., 2021; Zhang et al., 2021) and initial observations of a subset of the video recordings to ensure all relevant behaviours were captured. All videos were scored using the ethogram (Table 7-1) in the BORIS software (Friard and Gamba, 2016) by author FPJ who was blinded to the weaning treatments, but due to the visible nature of the different testing methodology (MH/UT) could not be blinded to this factor. Analysis began when the NO was placed inside of the pen, or in the case of the FP test when the kid entered the arena, and the door was closed behind them. A second observer (author HMV) watched and scored 1 kid's test for each timepoint and each pen (a total of 32 videos) in order to test interobserver reliability, however, this observer could not be blinded to weaning treatment due to their involvement in the daily running of the study during data collection.

Table 7-1. An ethogram of behaviours recorded during novel object and familiar person tests of artificially reared goat kids.

Behaviour	Type	Description
Vocalisation	Point	Generates noise
Retreat	Point	Retreat from novel object/familiar person. Backwards steps that begin when looking at/oriented towards the NO/FP, counted as one point regardless of number of steps until there has been a pause of greater than >5 seconds.
Jump	Point	Kid jumps against testing arena wall with all four feet.
Sudden movement	Point	A sudden, startle type movement, can be the whole or part of the body including the head or legs.
Interact with novel object or familiar person	State	Within 5cm of the object/human with face orientated towards it – may be sniffing or touching or chewing.
Locomotion	State	Movement (such as walking or running but excluding jumping or bipedal stance). Can be in any direction (forwards/backwards) but cannot be stationary movement. Minimum of 2 steps taken.
Latency to interact	State	Time in seconds from the novel object being placed inside the testing corridor until the kids' nose is within 5cm of the novel object/human
Stand still look	State	Standing on with all four feet still looking at the novel object/ familiar person for >5s, there may be head movements. The timer starts after 5 seconds have passed.
Bipedal stance	State	Kid stands on its back legs with its front legs on the testing corridor wall for >5s
Investigate arena	State	Placing the nose in contact with or less than one muzzle length from the walls or floor of the pen.
Rear against pen	Point	Kid jumps against testing arena wall with only front feet, back feet stay in contact with the floor. Differentiated from bipedal stance by momentary (<5 s) nature.
Out of view	State	Kid cannot be seen from the camera angle

7.3.6 Statistical analysis

Two deaths occurred during the study; one from pen 1 (GW, MH environment) from suspected urolithiasis, and one from pen 2 (AW, MH environment) from pneumonia – all their data was excluded from analysis. One kid (AW) from the MH environment, two kids (GW) and two kids (AW) from the UT environment were not being included in any analysis, due to be removed from testing as a result of distress, leaving a maximum total n of 28 kids. Individual n is presented for each summary as not all behaviours were displayed by all kids. When NO testing, each kid had 90 s to acclimatise to the testing pen. During this time, they had free access to the pen, and therefore when the NO was presented kids were located in different pen areas. To control for the effects of these different start locations on the kids' subsequent latency to interact with the object, the pen was visually divided into three equal sections (A – closest to the novel object, B – middle of pen, C – furthest from novel object). The videos were analysed to find kids in the different sections that immediately approached the novel object. These kids were timed, and the values were averaged per section. The variable 'Latency to interact with novel object'

was then adjusted to control for where the kid started their test. Calculations were performed using the following formulas: Section A = latency + average value for section C, Section B = latency + (average value for section C – average value for section B), Section C = no change. All statistical analysis was conducted in IBM SPSS Statistics (Version 27).

Inter-observer reliability

To inform aim 1, a Kendall's W test of concordance was carried out on the video data coded by both raters (25% of total videos) to assess interobserver reliability. Data were tested in their raw forms, and after agreement was established the duration data was transformed into proportional data.

Test-retest reliability – assessment of possible personality indicators

In line with aim 2, Kendall's test of concordance was carried out for each behavioural variable. Testing occasions were compared across time (tests 1-4) for the NO test and the FH test. Behaviours found to be concordant ($W<0.2$) were averaged across occasions to create one value per kid, these values were then retained for further analysis. The cut-off selected was 0.2, which is relatively low but was chosen due to the novelty of the study and the low sample size. If the same behaviour was found to be concordant between tests (NO/FH), and positively correlated the behaviour was averaged between tests. Variables that were found to not be concordant were discarded. Spearman's rank correlation was carried out to assess the relationship between 'Bipedal stance' in familiar human and in novel object tests.

Influence of external factors

Consistency is considered a key component of personality, therefore behavioural tests which elicit individually consistent behaviours can be considered 'good' tests of personality. To fulfil aim 3 and investigate behavioural differences between the two testing arena types (Modified home pen vs unfamiliar), the two arena types were compared using Kendall's W. These were calculated for every behaviour of each treatment group separately (pens 1 and 2; pens 3 and 4) and the resulting coefficients for each behaviour were compared between groups with Mann-Whitney U tests.

To assess the effects of external factors on the consistency of responses to personality testing, two General Linear Mixed Models (GLMMs) were used. Both models included kid ID as a random effect and Kendall's W for each kid across testing types as the dependent variable. Model 1 included test type, pen, and the interaction between test type and pen as independent variables, and model 2 included test type, weaning method, and the interaction between test type and weaning method as independent variables. Separate models were run as weaning

method and pen showed high multicollinearity. The best fitting model for each dependent variable was selected on the basis of lowest Akaike Information Criterion (AIC). Model residuals were checked for normality and homoscedasticity using visual assessment of Q-Q and residuals vs predicted value plots.

Association of repeatable behaviours and production metrics

Variables were tested for normality and transformed where necessary. In line with aims 4 and 5, a series of individual GLMMs were conducted to assess the correlation between repeatable behaviours that could indicate personality (as the independent variables) and production metrics (as the dependant variable). Each models structure was as follows; random effect of kid nested within pen; dependent variables: average daily gain, mean daily milk intake, mean number of milk feeds per day (square root transformed), day kid learnt to use the milk feeder independently, weaning treatment, and mean number of visits to the milk feeder postweaning; independent variables: bipedal stance (average across FH/NO, square root transformed), Stand still-look (FH, log10 transformed), Latency to touch novel object (LN transformed). Each model was checked and tested as per the section above.

7.4 Results

7.4.1 Inter-observer reliability

Kendall's test of concordance indicated good agreement between raters ($W=0.67$, $(n=2)$, $df(1)$, $p<0.001$).

7.4.2 Test-retest reliability – assessment of possible personality indicators

Results indicate that 'Bipedal stance' in both novel object and familiar human tests, 'stand still look' in the familiar human tests, and 'Latency until contact' in the novel object tests are repeatable personality measures for male goat kids (Table 7-2). There was a positive correlation between 'Bipedal stance' in FH and NO tests ($r(26)=0.81$, $p>0.001$), so these were averaged into 'Bipedal stance all' for further analysis. 'Stand still look' – familiar person test and 'Latency until contact' – novel object test, were also retained for further analysis.

Table 7-2. Results of Kendall's W tests for each behaviour of artificially reared goat kids in familiar person (n = 4) and novel object (n = 4) tests.

Behaviour	Familiar person test			Novel object test		
	N	Kendall's W	Significance	N	Kendall's' W	Significance
Bipedal stance	18	0.379[1]	<0.001*	18	0.234[1]	0.006*
Interact with NO/FH	28	0.124	0.016*	28	0.012	0.797
Investigate arena	28	0.037	0.356	28	0.027	0.502
Jump	24	0.124	0.031*	24	0.017	0.739
Latency until contact	28	0.030	0.462	28	0.202[1]	<0.001*
Locomotion	28	0.022	0.586	28	0.132	0.010*
Out of view	28	0.003	0.973	22	0.049	0.354
Stand still look	10	0.378[1]	0.010*	10	0.115	0.328
Vocalisation	28	0.132	0.010*	28	0.105	0.027*

Kendall's W values >0.200 are marked with a [1].
* Indicates significant differences at the alpha value of <0.05 (5%)

7.4.3 Influence of external factors

Results of Kendall's W tests showing the differences between testing environments can be seen in Table 7-3; the subsequent Mann-Whitney U test found no significant difference between the concordance coefficients of the two testing environments (p=0.579). With an alpha value of 0.05 and power of 0.80, post hoc analyses indicate that the sample size needed to detect a medium effect size for these model analyses would be 76 individuals (Sopher, 2024).

Table 7-3. Results of Kendall's W tests for each behaviour of artificially reared goat kids in novel object (n = 4) and familiar person (n = 4) tests for each testing environment (n = 2).

Test	Behaviour	Modified home pen			Unfamiliar arena		
		N	Kendall's W	Significance	N	Kendall's W	Significance
Novel object	Bipedal stance	15	0.313[1]	0.003*	3	N/A	
	Interact with NO/FH	14	0.051	0.543	14	0.099	0.247
	Investigate arena	14	0.098	0.250	14	0.055	0.510
	Jump	13	0.026	0.794	11	0.040	0.727
	Latency until contact	15	0.291[1]	0.004*	14	0.166	0.073
	Locomotion	15	0.035	0.665	14	0.334[1]	0.003*
	Out of view	15	0.188	0.037*	7	0.184	0.277
	Stand still look	5	0.253[1]	0.284	5	0.133	0.572
	Vocalisation	15	0.125	0.133	14	0.158	0.084
Familiar person	Bipedal stance	15	0.513[1]	<0.001*	3	N/A	N/A
	Interact with NO/FH	14	0.096	0.258	14	0.376[1]	0.001*
	Investigate arena	15	0.063	0.418	15	0.130	0.118
	Jump	13	0.183	0.068	11	0.145	0.189
	Latency until contact	15	0.154	0.074	14	0.059	0.481
	Locomotion	15	0.068	0.379	15	0.070	0.372
	Out of view	15	0.050	0.522	7	N/A	N/A
	Stand still look	5	0.244[1]	0.300	5	0.600[1]	0.029*
	Vocalisation	15	0.298[1]	0.004*	15	0.169	0.055

Kendall's W values >0.200 are marked with a [1]. N/A values are presented where the sample size was too low to complete the test.

* Indicates significant differences at the alpha value of <0.05 (5%)

Model 1: There were no effects of test type or test type*pen on kid consistency. There was, however, an effect of pen ($F(51)=4.399$, $p=0.008$, $n=29$). Post-hoc tests found that there were significant differences in kid consistency between pens 1 + 3 ($p=0.005$) and pens 2 + 3 ($p=0.012$). Kids in pens 1 and 2 (MH environment) were generally less consistent across testing occasions (Figure 7-2).

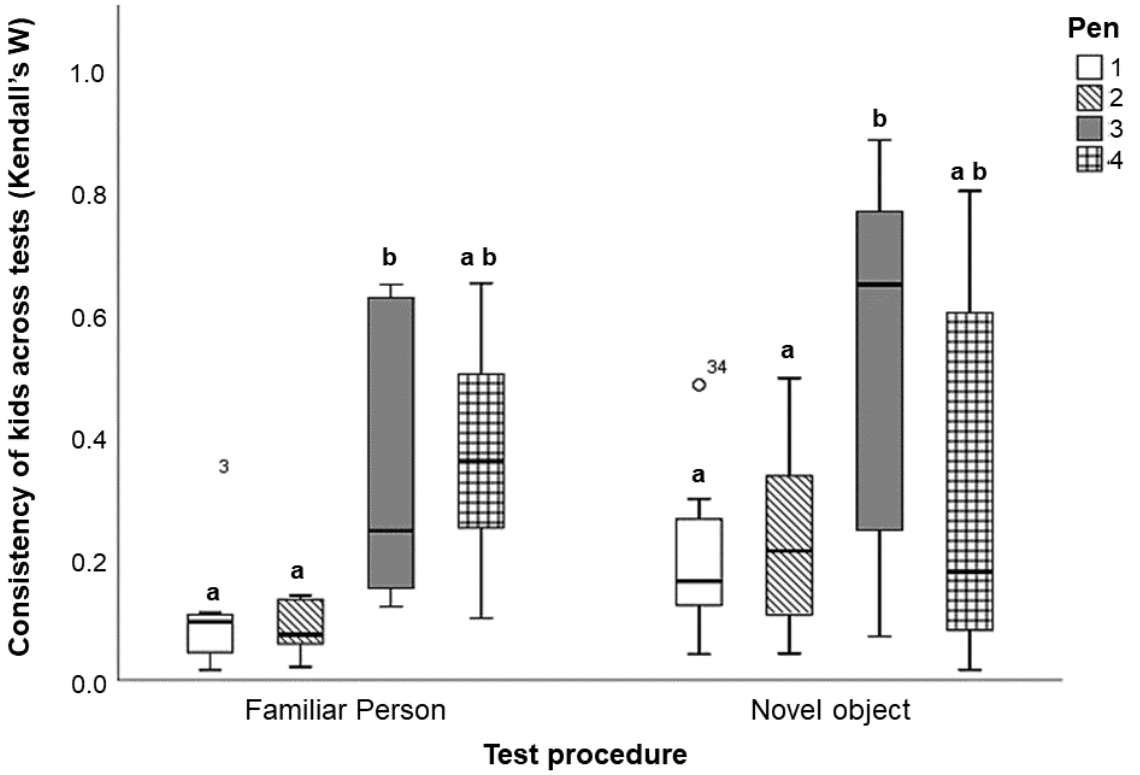

Figure 7-2. A boxplot showing differences in median Kendall's W values between pens of goat kids (Pens 1 and 2 = modified home pen environment; Pens 3 and 4 = unfamiliar testing environment) and test procedure (n=28).

Model 2: There were no significant effects of treatment, test type, or treatment*test type on kid consistency.

7.4.4 Association of repeatable behaviours and production metrics

There was a significant association between latency to interact with the novel object, and average number of daily milk feeder visits postweaning: an increase in average number of feeder visits was associated with a 0.688 second decrease in latency to interact with the novel object (t=-2.077, p=0.049, 95% CI= {-1.372, -0.004}) (Figure 7-1).

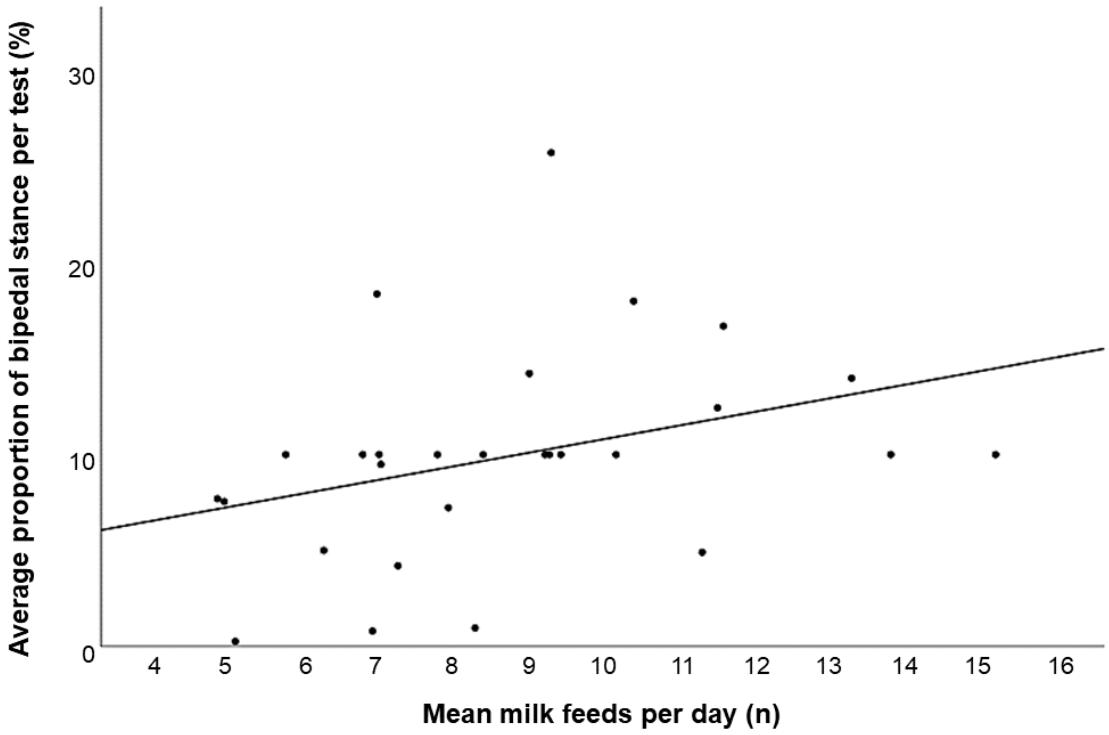

Figure 7-3. Relationship between the behaviour 'bipedal stance' performed by goat kids in novel object and familiar human tests and the mean number of milk feeds they fed in per day (R2 = 0.118, y=0.04+7.09E-3*x). Marker dots indicate individual kids (n = 28).

There was also an association between average number of milk feeds per day and average proportion of tests spent in a bipedal stance: an increase in milk feeds per day was associated with kids spending 1.72% longer in a bipedal stance (t=2.156, p=0.04, 95% CI= {0.08, 3.36}) (Figure 7-3). No relationship was found between ADG, average daily milk intake, weaning treatment, and day kid learned to use the feeder independently and any of the repeatable behaviours.

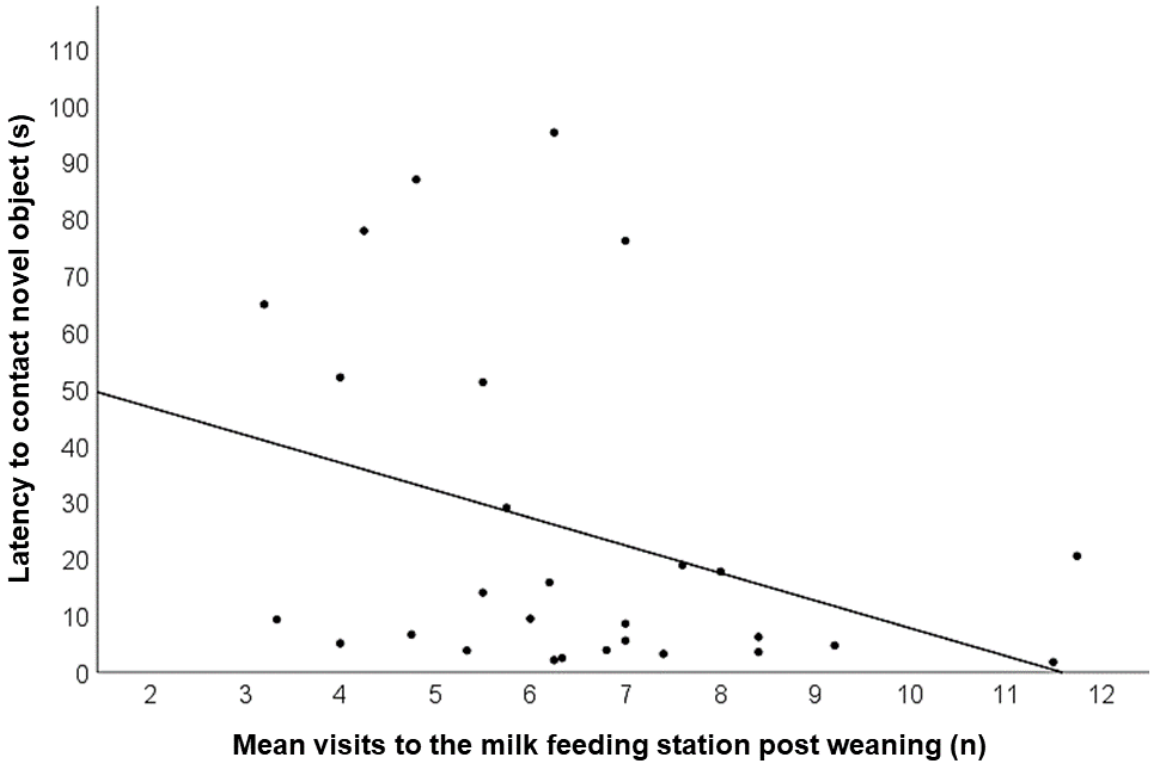

Figure 7-4. Relationship between the behaviour 'latency to contact' the novel object and mean number of visits to the milk feeding station post weaning of goat kids reared artificially (R2 = 0.122, y=56.54-4.88*x). Marker dots represent individual kids (n = 28).

7.5 Discussion

The methodologies described here elicited good interobserver reliability, which is an important aspect of ensuring repeatability. Out of the nine behaviours recorded, three ('bipedal stance' in both tests, 'stand still-look' in FP tests, and 'latency to interact' in NO tests) showed test-retest repeatability, therefore could be considered 'personality' indicators. Testing in an unfamiliar environment or modified home pen did not impact behavioural results when kids completed their tests, but more kids were removed from testing in the former due to distress. When investigating individual kid consistency, test type did not predict this, but the pen the kid was housed in did (with kids in pens 1 and 2 generally showing less consistency); however, due to a low number of both individual kid and pen-level replicates, distinguishing this relationship is difficult. No relationship was found between the repeatable behaviours (considered 'personality' indicators) and weight gain, daily milk intake, or weaning treatment, but an association between 'latency to interact with NO' and average milk station visits post-weaning, and between bipedal stance and daily milk feeds were identified.

Home pen tests are desirable for practical and welfare reasons because they avoid introducing handling effects and complete social isolation (see Forkman et al., 2007; Tecott and

Nestler, 2004 for further discussion). In our case, home pen modification was less feasible (carrying equipment into the home pen was practically challenging) than the unfamiliar environment, hence both were utilised to test for differences in the measured behavioural responses – none were found, implying that either could be used (depending on practicality). Modified home pens reduce social isolation (our kids were able to perform bipedal stance and see their pen-mates), and isolated fear tests have received criticism due to lacking species-appropriate consideration of gregariousness (Forkman et al., 2007). Whilst this seemingly did not influence our results, it likely affected those with the strongest behavioural responses to isolation, hence more kids being removed from the unfamiliar environment which had complete visual social isolation. Eliminating kids with strong behavioural responses from testing and subsequent analysis removes valuable information about behavioural reactivity but was necessary to protect individual kid welfare at the time of testing. Therefore, we suggest that the validation of testing methodologies that negate the need for social isolation whilst still accurately assessing individual responses is an important area for further research – particularly as welfare relevance would be improved (kids are most likely to experience stressful management changes whilst in a group). Toinon et al., (2021) reported results of group-level testing of goat kids, however they did not assess repeatability, so the validity remains unclear.

Although our study found no effect of testing environment on kid response, there was a pen-level effect which suggests a possible social factor related to group housing composition that impacts kids' responses. However, it has to be noted that this study was only able to include two replicates for each testing environment (four pens in total) which is a strong limitation. Whilst caution must be taken with regards to these results due to a low number of pen replicates in this study, recently, increasing attention has been paid to the effects of gut microbiota on farm animal health and behaviour (comprehensive reviews: Chen et al., 2021; Kraimi et al., 2019), and to its role as a driver of individual behavioural variation (reviewed by Davidson et al., 2018). Our kids were housed in four pens with solid sides, with pens one and two, and pens three and four were next to each other on opposite sides of a passageway (see Fig. 1) such that they may have been able to interact through joins in the pen; whilst this research is still in its infancy with relation to personality perhaps shared pen-level differences in microbiota (a 'social microbiome' being the microbial metacommunity of an animal social group: Sarkar et al., 2020) could explain some of the pen effect identified. We suggest that considering the gut microbiome research may be valuable to understanding individuality, and that aiming for a greater number of pen replicates would be desirable.

Meagher et al., (2016) hypothesised that low reliability in one of their calf experiments was due to a long test-retest interval (20 days) and that milk weaning occurred during the interval; our study chose to repeat tests with a four-day interval both pre and post weaning to

avoid this possible issue, however differences in consistency between the tests pre- and post-weaning were not observed. A further issue with response-based tests that measure voluntary approaches is that individuals who are simply 'indifferent' to the object or human may show similar behavioural responses, such as a long latency to approach, as kids that are truly fearful (discussed for mink in Meagher et al., 2011), which is why these tests do not only give us information on fear. Understanding and measuring additional behavioural responses which can differentiate between these kids is important, and vocalisations could provide further information on this. Whilst we did record vocalisations, we didn't attempt to assess differences between them as we felt this would not be reliable or repeatable without full acoustic analysis. We would highly recommend this be combined into future work as we anecdotally observed an apparent difference between shorter contact-type calls, and louder, longer, seemingly more distressed calls, a difference which has been found in previous acoustic analyses (Siebert et al., 2011).

Personality traits are inter-individual behavioural differences that are both temporally and contextually consistent (Koolhaas et al., 2010; Réale et al., 2007; Wolf and Weissing, 2012), and there is increasing evidence that they are related to growth and productivity of ruminants (Haskell et al., 2014; Neave et al., 2018). Whilst our study focused largely on indicators of fearfulness, which is not explicitly considered a dimension of personality by Finkemeier et al., (2018) (they discuss exploration, sociability, aggressiveness, boldness and activity), the behaviours observed here link to exploration, sociability and boldness. Furthermore, fearfulness as explored by the tests we have used has been a key interest of farm animal 'temperament' research (see Forkman et al., 2007 for a review) which Finkemeier et al., (2018) states is an aspect of, and highly interrelated with personality. Nonetheless, our study identified just three repeatable behaviours (meaning a principal component analysis typically used for these kinds of analyses could not be employed) and only two associations were found between repeatable behaviours (possible personality traits) and production metrics.

An association between average number of daily milk feeds and average proportion of tests spent in a bipedal stance was identified (higher daily milk feeds were associated with kids spending longer in a bipedal stance during testing). Whilst bipedal stance could reflect both exploratory and social personality traits (Nawroth et al., 2017), in reality the association identified in the present study was not strong and the average percentage increase was just 2% which could be circumstantial. Kids were likely performing this bipedal behaviour to widen their field of view, perhaps in response to isolation (to visually search for their conspecifics), or to generally look around and explore the environment, however there is little goat-specific research to inform our interpretation of its association with milk feeding. Dairy cow research has identified a link between alertness and feed consumption with cows that were more alert/ neophilic consuming more, and more fearful animals consuming less (Schwanke et al., 2022),

and calves that show higher exploration in novel object tests are faster to consume concentrate feed, have higher growth and intakes (Neave et al., 2018). Whilst bipedal stance could be indicative of alertness and exploration its links to feeding are unclear as there was no association found with overall milk intake or growth, but only how many feeds they consumed that milk in. However, our study was limited by an inability to record individual solid feed intakes, which prevented further exploring links with solid feeding behaviour.

An association between latency to interact with the novel object, and the average number of daily milk feeder visits kids made postweaning was identified, with kids visiting the milk feed station more having a lower latency to interact with the novel object, however this difference was on average less than 1 second which is unlikely to have much practical significance, furthermore there was distinct clustering of individual kids visible in Figure 7.4, there appeared to be a group of kids that were slow to contact the novel object and had fewer milk feeding station visits post weaning, there . This is likely to reflect that these kids showed greater levels of activity/ exploration and general 'boldness' (a personality trait that has been identified by principal component analysis in juvenile goats; Finkemeier et al., 2019), which could be linked to a more pro-active style of coping with the management change of weaning. It may also reflect a generally higher level of neophilia with a desire for novelty reflected by more frequently visiting the slightly different environment of the milk feeding station, indeed Nawroth et al., (2017) classified latency to interact within an 'explorative' personality trait category.

Developing our understanding of behavioural individuality could have practical implications; in cattle personality traits have been shown to have moderate to high levels or heritability (Haskell et al., 2014; Stirling et al., 2002) which could influence selective breeding programmes. Furthermore, individuals less suited to living under commercial conditions are likely to experience poorer welfare, which is of concern for reasons of ethics and associations with reduced productivity (Voisinet et al., 1997; Burrow and Dillon, 1997).

The study size needed to assess personality correlation estimates accurately has been proposed as 250 individuals (Schönbrodt and Perugini, 2013), which with limited research funding and farm sizes is realistically impossible to achieve in most individual studies; indeed, these practical constraints limited both individual kid and pen-level replicates and influenced the level of confidence in the results of the current study. The power analysis reported in 7.4.3. suggests that to detect a medium significant ($P<0.05$) effect size with our model structure, data from 76 individuals would be necessary, therefore this study which includes data from 28 kids was sizeably under powered which is likely reflected in the lack of repeatable behaviours identified. As per Meagher et al., (2017)'s recommendation we agree that multi-study replication with meta-analyses should be the gold standard and hope that the information reported in our study regarding testing methodologies is a step towards a standardised protocol. With the

recent establishment of the ‘Many Goats’ project (www.themanygoatsproject.com) following on from the success of multi-lab collaborations including the ‘Many babies’ project (Frank, 2016), further work on goat personality with larger sample sizes should be forthcoming, but we stress that this should consider all life stages and not just adults.

7.6 Conclusions

The behavioural ethogram and testing procedures used elicited good interobserver reliability, and it was found that test type did not predict individual consistency, but pen did, which warrants further investigation with a greater number of pen replicates. In kids tested repeatedly before ten weeks old only three out of nine behaviours recorded showed repeatability which suggests they could be indicators of personality; ‘bipedal stance’ in both tests, ‘stand still-look’ in FP tests, and ‘latency to interact’ in NO tests. There were few links between the personality indicators identified and production metrics; no correlations were found with weight gain, milk intake/day, or weaning treatment, but a trend towards effect of ‘latency to interact with NO’ on average milk station visits post-weaning (shorter latency to interact = more visits to the milk station), and an effect of bipedal stance on milk feeds/day (more time in bipedal stance = more feeds) were found. Whilst the results of this small-scale study of artificially reared male goat kids should be interpreted with caution due to a lack of statistical power attributed to limited individual and pen-level replicates, it was found that testing environment did not statistically affect fear behaviours of the kids that completed testing, but the unfamiliar environment resulted in more distress-related removals therefore the ability to record the full diversity of kid responses (with the most behaviourally reactive kids’ data removed) is reduced, consequently a modified home pen environment is recommended wherever practical, validation of group testing techniques is recommended as a key area for future research.

7.7 Ethics approval

Ethical approval was granted by the University of Reading, School of Agriculture, Policy and Development, ref. 001561 and Dalhousie University, ref. 2021-010.

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8. General discussion

8.1 Introduction

The body of research presented within this thesis aimed to 'investigate the behaviour, productivity, and individuality of artificially reared goat kids, during the milk feeding period and weaning transition, in order to make recommendations for how on-farm management could be improved' – an overarching aim fulfilled by five key research questions (Figure 8-1).

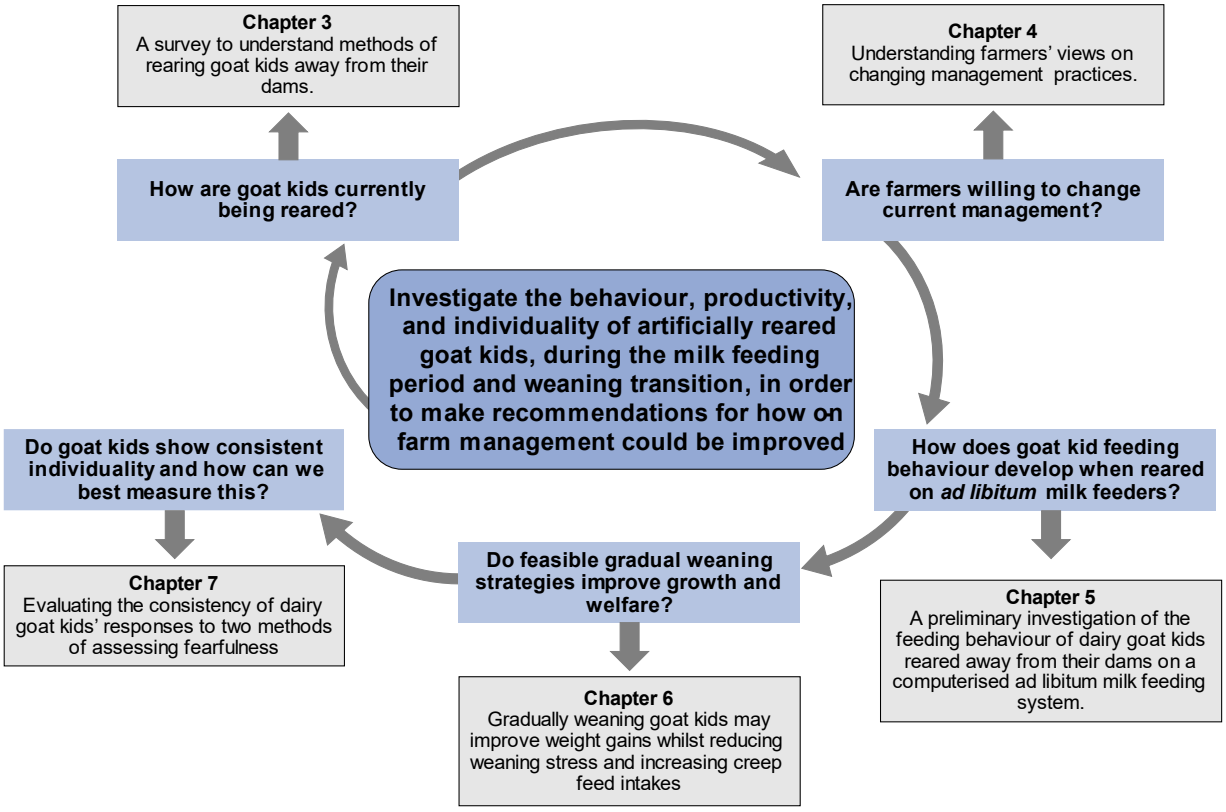

Figure 8-1. An overview of the thesis aim, research questions and corresponding research chapters.

This final chapter summarises the contribution each research chapter makes to the literature and how they impact goat kid management as a whole, alongside an overview of how the research findings pinpoint areas that are recommended for future research to fill remaining knowledge gaps. Wider implications of this body of work for both the goat industry, and for science, will be postulated. To recap the studies that make up this thesis and how they address the overarching aim they are presented alongside their corresponding research chapters in Figure 8-1.

8.2 Contribution of thesis research studies to the literature

The literature review (Chapter 2) highlighted that the body of evidence regarding the artificial rearing of goat kids, applicable for real-world management, is lacking and that the majority of goat kid management is extrapolated from findings of studies on dairy calves which may not be appropriate due to species-specific differences. Previously an understanding of how

goat kids reared under standard commercial management behave and develop during this pre-weaning and weaning period was absent which highlighted that baseline measures needed to be established. Evidence from calf studies clearly demonstrates that gradual weaning strategies improve the overall welfare of individuals, but a lack of technology utilised for goat kids limits the applicability of this research, and therefore strategies feasible for on-farm use needed to be identified, developed, and trialled. Furthermore, consideration of individuality is an important aspect of understanding animal welfare that is currently under-considered in farm animal systems, and particularly understudied in goat kids. The research chapters present the results of five studies designed to address knowledge gaps identified by the literature review, each in the format of a journal article; four of which (Chapters 3, 4, 5, and 6) have been published and the last (Chapter 7) has been submitted for publication.

8.2.1 How are goat kids currently being reared?

Responses were collected from anyone rearing goat kids away from their dams, which differs from previous surveys that have focused on dairy goats (Anzuino et al., 2019; Belanger-Naud et al., 2021; Hempstead et al., 2021; Todd et al., 2019). The most common milk feeding method was bottle feeding - differing from dairy goat surveys which found ad libitum automated feeding systems are more common (Anzuino et al., 2019; Belanger-Naud et al., 2021; Hempstead et al., 2021; Todd et al., 2019), likely related to the overrepresentation of smaller farms in our sample (it was found that those rearing >100 kids were more likely to feed milk ad libitum – probably reflecting the labour intensity required for bottle feeding). Weaning decisions were typically based on a target age which agrees with data from the United Kingdom (Anzuino et al., 2019) but differs from New Zealand farms which more commonly used weight (Todd et al., 2019) and Canadian farms which use a combination of age and weight (Belanger-Naud et al., 2021). A not insignificant number (19.3%) reported that they did not use either a target weight or age and it was unclear how they decided when to remove milk access which is a concern when it comes to adequate rumen development and subsequent ability to cope (both physiologically and psychologically) with the removal of milk nutrients. The physical process of milk removal was typically gradual, which is positive as in calves it is known to promote better welfare than abrupt weaning (Roth et al., 2009; Weary et al., 2008). Abrupt weaning was significantly more likely to take place from ad libitum milk feeding systems which are used to rear greater numbers of kids, and literature demonstrates that ad libitum milk feeding results in lower solid feed intakes (Lu and Potchoiba, 1988) which is particularly problematic for overall welfare when combined with abrupt weaning (Weary et al., 2008). The vast majority of farms were providing forages and concentrate feeds from an early age which is essential to ensure familiarity pre-weaning, but less than half of those feeding commercial blends were using a goat-specific product – something which does not happen for other major livestock species and

could impact rumen development and nutrition. It was promising that most supplied enrichment as this is likely to improve kid welfare (for a review of how enrichment can improve farm animal welfare see: Bolt and George, 2019). Overall, the findings of this survey study suggest that there are divergent practices in smaller-scale bottle fed versus larger-scale ad libitum milk systems, which reflect differing system needs and goals in terms of material and labour inputs and in turn, profitability, and has potential impacts on the applicability of research findings that aim to improve goat kid welfare through on-farm management change.

8.2.2 Are farmers willing to change current management?

This study (Chapter 2) utilised the same farmer survey as above, and despite differing systems being encompassed in the survey there were clear common trends. Farmers currently abruptly weaning from ad libitum milk systems showed consistent unwillingness to change to any gradual weaning strategies and based on their identified concerns for future gradual weaning recommendations to be feasible they must be targeted at pen-level strategies. There is significant evidence from calf literature that gradual weaning has benefits for growth and welfare above abrupt weaning (Scoley et al., 2019; Weary et al., 2008) yet goat farmers do not seem to be aware of, or willing to, consider these methods, perhaps greater communication between, and not just within, sectors could highlight management techniques that may be beneficial to apply across species and farm types. This could also be due to a lack of feasible group-level weaning strategies and research or industry advice to address health concerns, as these were common themes reflected in farmers responses – highlighting the importance of communicating with farmers to understand barriers to change in order to perform research tailored to addressing these. Farmers were far more likely to provide enrichment in the form of climbing or loose items rather than swinging items, due to a large number of concerns regarding safety of climbing items – it has been suggested that concerns could stem from goats lacking early life experience of enrichment and therefore being more likely to gain injuries (Zobel and Nawroth, 2020).

Overall, all factors scored highly in their importance to farmers' decisions regarding changing management practices, demonstrating that system-related change relies on consideration of multiple factors at once. It is accepted that farmers as the party responsible for the management of animals under their care, are the key to implementing practices beneficial to animal welfare (Albernaz-Gonçalves et al., 2021) but often find proposed changes difficult to implement (Kauppinen et al., 2010), therefore it is a core strength of this thesis that the survey enabled farmer views to be integrated into research planning.

8.2.3 How does goat kid feeding behaviour develop when reared on ad libitum milk feeders?

When reviewing literature and speaking to farmers, industry advisors and academics it was clear that no data quantified how goat kids' feeding behaviour develops when reared on commonly used ad libitum milk systems therefore the Chapter 4 study was planned. To record individual milk intakes, a calf milk feeder was adapted, and milk feeding stations of the appropriate size for goat kids were created, making this the first published study to utilise individualised technology for goat kids; consequently, there is little directly comparable literature. Kids showed marked individual behavioural differences, particularly in their ability to learn to use the milk feeder, and in how many milk feeds they chose to consume each day. The most significant finding was that both milk intake per day and per meal was rising at the industry standard time of weaning, and a dramatic impact of abrupt weaning was seen on feed intakes with sudden and steep intake increases. It is widely recommended that weaning should not occur before daily concentrate feed intakes are > 250 g (Hart and Delaney, 2016; Lamlac, 2019) a guideline which the study kids simply did not meet by an average of 186 g/day which is a key concern for all kids abruptly weaned from ad libitum milk supplies. Whilst the sample size was small for logistical reasons (the Covid-19 pandemic prevented data collection on a commercial farm and the subsequent research facility was size limited) this study successfully quantified the feeding behaviour of goat kids reared under typical commercial management and identified significant inter-individual variation and identified potential issues around the transition to solid feeds when milk is provided ad libitum until abrupt weaning.

8.2.4 Do feasible gradual weaning strategies improve growth and welfare?

Understanding farmers' reservations regarding gradual weaning (as described in Chapter 4) enabled this study to be tailored to use a gradual weaning strategy feasible for use on-farm and ensure the variables recorded would address farmers concerns. Due to differing research conditions (Experiment 1 was conducted on a commercial farm whereas Experiment 2 was under research conditions reflective of commercial management). some conflicting outcomes arose, which highlights the challenges around reproducibility of animal data.

This research indicated that a method of gradual weaning (pen-level milk teat removals) feasible for on-farm use may positively affect weight gain; had little impact on rearing costs (gradually weaned kids costing on average £1.13 less to rear from 35-70 days of age); resulted in increased creep feed and water consumption, and decreased behaviours indicative of frustration, which may improve the welfare of goat kids reared on artificial milk supply systems. In terms of acceptability to farmers, the commercial farm reported that the method of gradual weaning used was feasible, and no health concerns or issues related to compensatory milk

feeding or increased competition were identified; all of which were common farmer concerns identified in Chapter 4. Many farmers believe that academic research findings do not reflect the conditions experienced in the 'real-world' and therefore are not applicable to their situation (Alarcon et al., 2014), and there is strong evidence that participatory engagement in the early stages of research planning results in findings that are feasible for use on-farm and therefore have the greatest potential of adoption (Rose et al., 2018); the method of gradual weaning trialled in this study could be feasibly applied for use with ad libitum milk feeding machines with only minimal adaptation of current management.

8.2.5 Do goat kids show consistent individuality and how can we best measure this?

As individuality is often under considered in farm animal research (Winckler, 2019) and has been linked to an ability to cope with weaning (lambs: Çakmakçı et al., (2021)) as well as individual feed intakes (calves: Neave et al., (2018)) this study was designed to evaluate if kids show inter-individual variation, how this can best be evaluated, and if it relates to other traits. The behavioural ethogram and testing procedures used elicited good interobserver reliability which is an important aspect of ensuring reliability. Testing in either an unfamiliar environment or modified home pen did not impact results of the kids that completed their tests, suggesting that either can be recommended, but more kids were removed from testing in the former due to distress –likely related to a criticism that these tests do not sufficiently consider group-living species' gregariousness (Forkman et al., 2007). Eliminating kids with strong behavioural responses removes valuable information, therefore tests that allow for reduced social isolation should be used wherever possible.

Only three out of nine behaviours recorded showed some level of repeatability and no correlations were found between these repeatable behaviours and weight gain, milk intake/day, or weaning treatment. However, some weak correlations were identified; kids that visited the milk feed station more postweaning showed a lower latency to interact with the novel object, which could link to greater levels of activity and general 'boldness' (Finkemeier et al., 2019) relating to a more pro-active style of coping with weaning, and possible higher neophilia (the milk feeding station represent a different environment, and latency to interact has been classified as 'explorative': Nawroth et al., (2017)). Higher numbers of daily milk feeds were slightly associated with kids spending longer in a bipedal stance during testing, which could reflect exploratory and social personality traits (Nawroth et al., 2017) as they are likely performing this behaviour to widen their field of view, perhaps in response to isolation or to explore the wider environment visually, but there is little goat-specific research to inform our interpretation of this association. Dairy cows that are more alert/ neophilic consume more feed, and more fearful animals consume less (Schwanke et al., 2022), and calves with higher

exploration in novel object tests are faster to consume concentrate feed and have higher growth and intakes (Neave et al., 2018); bipedal stance could be indicative of alertness and exploration however we found no association with overall milk intake or growth so the interpretation of this association is unclear. Overall, this study identified methodologies with good reliability, found three repeatable behaviours indicative of personality which had some associations with other metrics, and recommends that a home pen environment should be utilised wherever practical to minimise distress; these findings can be used to inform future methodology and investigate associations between feeding behaviour and personality and how this impacts the success of weaning techniques.

8.3 Key strengths and limitations of the studies

The body of work presented here has both strengths and limitations. Overall, most limitations related to practical and financial restraints, alongside the challenges of collecting animal-based data during the Covid-19 pandemic which led to limited sample sizes. A key strength of this thesis however lies in its employment of participatory engagement approaches by utilising mixed methodologies to ensure the applicability of results through tailoring animal-based research to farmers' views. As a result, the research was situated in the real world, studying goat kids under typical management conditions, which brought complexity to the design and led to some acknowledged limitations. This pragmatic approach generated data most applicable to commercial farm situations and these smaller-scale, baseline data providing projects need to be published in order for future research to be effectively planned, and for funding on a larger scale to be justified and obtained. This research was inspired by speaking to academics and farmers, all of whom highlighted the importance of understanding the key questions addressed throughout Chapters 5, 6 and 7 and that the resulting knowledge is essential to planning future research. Therefore, despite some methodological limitations, the data presented are essential baselines on which to build future research, and specific limitations as related to each of the research chapters are discussed below.

8.3.1 Survey-based data

Given that farmers are responsible for the day-to-day management of animals under their care, it is well accepted that they are the party responsible for implementing practices that can be beneficial to animal welfare (Albernaz-Gonçalves et al., 2021), but they often find proposed changes difficult to implement (Kauppinen et al., 2010). Therefore, it is a key strength of this thesis that farmer views were integrated into research planning. Collecting data from anyone who reared kids away from their dams for any purpose is both a strength and a

weakness of this study; however, despite this diversity, common themes prevailed across a large heterogeneous sample and deserve research attention.

Underlying perceptions that impact farmers' decision making are often overlooked (Blackstock et al., 2010) and this survey attempted to begin addressing this. However, consideration of wider sociodemographic factors would have been beneficial as it may have identified associations likely to influence welfare as has been found by other research (Albernaz-Gonçalves et al., 2021; Lianou and Fthenakis, 2021). A comprehensive review of factors that influence farmers' views on animal welfare reported that knowledge, empathy, demographic characteristics (gender, age and experience) and social pressure have been established by literature as having considerable impacts (Balzani and Hanlon, 2020). Age and experience seem to be particularly influential to the likelihood of adoption of higher welfare practices; in Scotland, 60% of livestock farmers reported that they would not be willing to adopt and apply new management (Liu et al., 2019) which was strongly associated with age; increased farmer age (which is associated with experience) was a good predictor of those unwilling to make changes. Indeed, similar has been reported for New Zealand sheep farmers, with those aged over 50 years using fewer health management tools including vaccinations (Corner-Thomas et al., 2015). Therefore, it seems likely that age may have related to the unwillingness to adopt gradual weaning techniques identified in Chapter 4 and this could have helped identify farmers more likely to be early adopters of this kind of management.

Overall, the survey results of Chapters 3 and 4 were skewed towards those rearing a small number of kids which is a limitation as the focused animal studies were tailored towards larger scale commercial management. These systems rear more kids per year and therefore this thesis targeted research to improve welfare in these larger systems due to a greater potential to improve animal welfare. Collecting data from anyone who reared kids away from their dams for any purpose is both a strength and a weakness of this study, however, despite this diversity common themes were identified, and associations found, highlighting that there are differing system needs but that a number of themes prevail across a large heterogeneous sample and deserve research attention. Furthermore, the limitations of an anonymous recall-based survey approach must be recognised, and how the networks available for distributing the survey are likely to bias results to certain networks. A more systematic approach utilising milk buyers or other sources that have a database of farmers could improve the representation of larger commercial farms which as identified by this survey have differing management challenges.

In-depth interviews by Albernaz-Goncalves et al., (2021) found that economic, technical and social factors restrict intensive pig farmers ability to uphold animal welfare, they also identified a common unwillingness to adopt practices to improve welfare, in fact they state that

all practices presented as possibilities to improve welfare were considered unacceptable by farmers, which was generally associated with issues relating additional production costs or labour. Chapter 4 of this thesis identified clear common barriers to the implementation of higher welfare practices on farm and can help to tailor future research to mitigate these. This was practically implemented in Chapter 6 when data was collected specifically to alleviate farmer concerns (relating to cost and compensatory feeding). Farmer attitudes are integral to the adoption of new practices (Rehman et al., 2007), and it is recommended that farmers should be involved in research planning to ensure that resulting findings are feasible and have the greatest possible potential of adoption (Rose et al., 2018). Farmer views were integral to the planning of the research presented in this thesis, and resulted in the tailoring of animal-based studies which could improve the likelihood of higher welfare practices being adopted for use.

8.3.2 Animal-based data

The Covid-19 pandemic and resulting lockdowns and local restrictions prevented data collection from commercial farms during 2020 and 2021, therefore the studies included in Chapters 5, 6, and 7 had resulting methodological limitations. These studies were conducted at the researcher's home farm location to prevent lockdown access issues and subsequently the sample size was limited by physical space and funding availability. Furthermore the (UK) Welfare of Animals (Transport) Order 1997 (S.I. 1997 No. 1480) Article 6, paragraph 3 states that kids less than one week old must not travel >100km and the Animal and Plant Health Agency require a travel license for journeys >64km. Therefore, a limited radius for sourcing the goat kids was imposed – unfortunately, farms within this radius could only provide male kids. Had female kids been available, in order to rehouse them they would have had to be disbudded under full anaesthesia by a veterinarian (per UK regulations), a procedure which is considerably expensive and would have impacted their behaviour and possibly disrupted the studies. These considerations resulted in the limitation of only collecting detailed data from male kids that had to be castrated (in order to be rehoused at the end of the study). Overall, there is not sufficient evidence or rationale that supports expected sex differences in many variables at this age when using castrated male kids (as discussed in Chapter 5), hence the work presented is still relevant to goat kid rearing as a whole. The resulting data documenting feeding behaviour under typical commercial management, feasible gradual weaning strategies, and an investigation into individuality, is information which simply did not exist before and can be used to inform further research on this understudied species.

Information obtained from stakeholders within a participatory research-based approach should be followed up with on-farm or animal-based research projects (Vatta et al., 2011) to ensure thorough investigation of proposals. A key strength of the animal studies presented in

this thesis was the tailoring of animal management to current commercial conditions, and strategies that would be feasible for farmers to use due to the information obtained in Chapters three and four. Many farmers believe that academic research findings do not reflect the conditions experienced in the 'real-world' and therefore is not applicable to their situation (Alarcon et al., 2014), and A DEFRA commissioned review presents strong evidence that participatory engagement in the early stages of research planning results in findings that are feasible for use on-farm and therefore have the greatest potential of adoption (Rose et al., 2018). The careful consideration of current real-world management, and farmers concerns enabled the research presented in this thesis to be tailored to current standard commercial management ensuring applicability of research findings and an ability to communicate this to farmers. Farmers understanding of welfare is linked to their perception that it is largely related to biological functioning and even when indicators of poor welfare are present most farmers believe their welfare standard to be acceptable and see no justification to invest in improvements (Albernaz-Goncalves et al., 2021), particularly as there is a perception that improving welfare is costly. Therefore, a key strength of Chapter 6 is the inclusion of a cost analysis which demonstrated that small, feasible management changes to improve the weaning tradition were at least equal to, if not slightly less economically expensive to employ than current management.

Throughout the animal studies presented there was a lack of funding to perform research on a greater scale or under more controlled conditions with the full use of technology that is widely utilised for dairy calf research, resulting in an inability to record individual solid feed intakes. Individualised data on solid feed and water intakes would have been highly beneficial to the gradual weaning investigation (Chapter 6), as calf evidence shows that gradual weaning does not improve performance for calves with low starter intake at the beginning of the weaning process (Bittar et al., 2020). This would have further strengthened the study investigating individuality (Chapter 7) by enabling links between personality and feeding behaviour to be explored (such as has been explored for calves: Neave et al., 2018). It would have been further beneficial to the research presented in Chapter 6 to include measures of rumen development, however there are no validated non-invasive measures of rumen development and the proxies that exist for cattle (such as electronic rumination-monitoring system validated for calves: Burfeind et al., 2011) have not yet been scaled down and validated for use in adult goats, let alone in young goat kids that have very small jaws. Therefore pen-level solid feed intakes were the only measure that could be recorded and cannot be considered a direct indicator of rumen development, furthermore it is difficult to accurately quantify forage intake particularly as it is much more prone to being picked up and then dropped away from the collecting area. With regards to Chapter 6 additional limitations related to working on a

commercial farm were experienced during Experiment 1 which resulted in an inability to individually ID male kids or to mark any for individual behavioural identification. Furthermore, the post weaning period being restricted to just four days (due to the kids being rehoused) resulted in post weaning growth observations that are unlikely to accurately reflect weight gain.

Overall, all the animal studies were limited in statistical power due to the lack of both individual and pen level replication resulting from practical (barn size and labour) and funding constraints, which limits precision and accuracy (Quinn and Keough, 2002), and increases the likelihood of type two errors resulting in the null hypothesis being inaccurately rejected (Cohen, 1988). This limitation is clearly evidenced by the power analysis conducted in section 7.4.3. finding that for the model structure used, 76 individuals would be needed detect a medium sample size with the widely considered acceptable 80% power, and only 28 kids could be utilised for that study. This is a particularly important consideration for behavioural analysis when pen-level factors are more likely to impact results and therefore caution should be taken with regards to pseudo replication, however pen was accounted for whenever possible in statistical analysis. As pen-level effects were observed in Chapter 7 it is suggested that greater pen replication is needed in the future. Whilst it may have been beneficial to split the kids into smaller groups to enable greater pen replication (such as was done by Zobel et al., 2019 who split 45 into 3 pen replicates for each of 3 treatments), the studies presented in this thesis aimed to be reflective of standard commercial management which is to house kids in much larger groups with higher competition for each ad libitum milk teat, and it was not possible for the ad libitum milk feeder used to supply any more teats than already used.

Due to the novelty of the work presented in this thesis an estimate of effect size and variability within pens was not available and therefore it could not be assessed *a priori* how many pen replicates were needed to obtain acceptable statistical power. Furthermore, there is no consensus on what constitutes a biologically significant effect, and it is particularly difficult to determine this in relation to exploratory behavioural and individuality data. These factors are problematic within most published animal studies, and in the relevant goat kid literature around weaning and personality to date no power analyses were included in published articles. A review paper discussing statistical power of animal behaviour research identified that of 748 tests publishing non-significant results not one reported a power calculation, and on average the statistical power was just 13-16% to detect a small effect (Jennions, 2003). This is a common issue in the animal welfare literature as well with zero out of 45 empirical research papers published in the 2009 journal ‘Animal Welfare’ reporting a justification of sample size, or reporting effect size (Hawkins et al., 2013). Whilst statistical power is clearly problematic within animal research, a review concluded that statistical power should not be considered a criterion for publication as synthesis of results of multiple smaller studies will result in more valuable

information than integrating information from fewer larger studies (Jennions, 2003), something that the information presented in this thesis may be able to contribute towards in the future.

8.4 Implications and recommendations for commercial goat kid management during the milk feeding stage and weaning transition

To protect and improve goat kid welfare, current rearing methods had to be assessed (Chapter 3) and restricting factors for changing management identified (Chapter 4) and from these chapters and the subsequent animal studies it is clear that ad libitum milk system management could be adjusted to improve kid welfare. Currently codes of practice in the United Kingdom do not provide sufficient advice on how to safeguard the welfare of goat kids reared on these systems and these should be updated and improved (DEFRA 2023: Table 8-1) as the Code came into operation in 1989. The only additional advice given for goat kids is with regards to colostrum management, disbudding, and castration; no inclusions discuss stocking density, the challenges of competition with shared milk teats, or weaning processes. This contrasts to the codes of practice provided by the National Farm Animal Care Council which provides greater detail regarding environmental comfort, recommended stocking densities explicitly for pre weaned (0.6m^2/kid) and weaned kids (0.9m^2/kid), and entire sections (4.3 and 4.4) devoted to ‘raising kids on milk or milk replacer’ and ‘Weaning’ (NFACC, 2022).

Table 8-1. The entirety of information given regarding 'artificial rearing' of goat kids provided by the DEFRA Code of recommendations for the welfare of goats (2023).

Point	Advice given
38	Artificial rearing can give rise to problems and, to be successful, requires close attention to detail and high standards of supervision and stockmanship. Particular attention should be paid to cleanliness and hygiene.
39	Young kids should always have access to milk substitutes or be fed at least 2 or 3 times each day. Milk from other dams could constitute a disease risk. Fresh fibrous food should be available from 1 to 2 weeks of age.
40	Some form of safe supplementary heating, particularly in the early days of life, may be necessary.
41	A dry bedded lying area and adequate ventilation should be provided at all times.

Whilst ad libitum systems reduce the labour requirements for milk feeding (which is likely why they are linked to rearing greater number of kids: Chapter 3) despite their benefits (particularly in relation to growth and behavioural expression: Budzynska and Weary, 2008; Scoley et al., 2019) they represent a number of potential welfare challenges; therefore, this

section will focus on feasible management changes which would improve the welfare of kids reared on these commonly commercially used ad libitum systems.

Chapter 5 suggests that ad libitum milk fed kids are very likely not meeting solid feed intake guidelines at the industry standard time of weaning (in the UK 56 days) and that kid welfare is likely compromised by abrupt weaning from ad libitum systems (as has been clearly demonstrated by prior calf literature: Jasper and Weary, 2002; de Passillé et al., 2011), therefore it is highly recommended that farmers explore the possibility of utilising the simple pen-level method of gradual weaning (teat access removal) proposed and investigated in Chapter 6. The timings proposed within Chapter 6 could be easily modified to fit with farmer schedules, but caution should be taken regarding beginning gradual weaning any earlier than proposed or increasing milk-teat removal times without further investigation. This is supported by research on gradual weaning of goat kids that begin at a later age (three months) and occurred over a shorter period of time (six days) finding that weight gain was not negatively affected during, or four days post, weaning (Zobel et al., 2019). It is likely that older kids are naturally consuming more solid feeds and are more physiologically adapted to the process of milk removal which highlights the importance of age to weaning success, however it is unlikely that countries already weaning commercially at a younger age (such as the 56 days identified as standard in the UK by Chapter 3) will increase weaning age due to the increasing cost of milk replacer challenging the financial viability of kid rearing. Other strategies to increase solid feed intakes are highly recommended, such as improving natural behaviour expression by allowing kids to feed at head height (which has been demonstrated to increase feed intakes in adults: Neave et al., 2018), and the importance of basic good management practices such as ensuring a constant, clean, and fresh supply of water and feed in ways that reduce feeding competition.

Farmers utilising ad libitum milk systems typically allowed 6-10 or 11-20 kids per shared milk teat (Chapter 3) which could have ramifications on feeding competition levels and social dynamics within the pen; this is rarely a problem in calf systems as they typically enter a fully protected individual milk station to feed, however in goat farms the milk teats are available on an open surface and there is no literature investigating the impacts of this. When kids had to feed in a milk station which protected their head and shoulders there were very few displacements observed (Experiment 2, Chapter 6), which could have resulted in the contrasting data from Experiment 1 (Chapter 6 conducted on a commercial farm had unprotected milk teats), subsequently the use of protected areas for the teat rather than on an open surface should be encouraged, particularly as the ability of goat kids to cope with these kinds of competitive interactions is likely to vary considerably between individuals.

8.5 Future outlook for goat kid rearing management and research

To ensure welfare is a priority, future goat kid rearing facilities should aim to foster an environment that is conducive to the expression of highly motivated species-specific behaviours whilst reducing the detrimental effects of stress associated with key management changes such as separation, social mixing and weaning. Chapter 5 identified that ad libitum milk rearing alongside abrupt weaning presents welfare concerns around solid feed intakes and weaning stress caused by a lack of psychological and physiological preparation for the transition between milk and solid feed diets. Future research that builds on the initial investigation of a feasible pen-level gradual weaning strategy presented in Chapter 6 should be of high priority and should focus on strategies aiming to increase solid feed intakes and mitigate stress related to weaning whilst finding the optimum balance which maintains all the evidenced benefits of high milk intakes provided by ad libitum milk systems (such as improved growth and behavioural expression: Appleby et al., (2001); Diaz et al., (2001); Jasper and Weary, (2002)); particular attention should be paid to identifying optimal timings for milk removal during the crucial gradual weaning transition stage. This information should be incorporated into current codes of practice for goats as currently the UK recommendations do not mention weaning at all (DEFRA, 2023), whereas the Canadian codes state that weaning should not be before 6 weeks of age/ 2.5x birthweight, should be gradual ‘over several days’ and that before weaning kids should be ‘consuming adequate amounts of forage, solid feed, and water daily to maintain growth and health’ (NFACC, 2022). Codes of recommendations should be more specific regarding optimum forage levels and weaning practices, with greater consideration given including practical recommendations for how gradual weaning can be incorporated into ad libitum milk systems as this is a key feasibility challenge for farmers (Chapter 4).

Now that the utility of a calf milk feeding machine for goat kids (Chapters 5 and 6) has been demonstrated there are huge implications for the ability to collect more data and further uncover the relationships between management practices and individual goat kid health, behaviour and subsequent welfare in the future. However, to ensure results are applicable for goat farms which are unlikely to invest in individualised calf milk feeding technology this research should focus on using these individualised feeders to identify techniques that improve welfare, or indicators of other factors which impact welfare, which could be employed on farm or within welfare assessments without a direct need for individualised milk feeding technology. The distinct individuality of milk feeding behaviour identified by this technology in Chapter 5 and further explored with regards to response to fear tests in Chapter 7 is an area which needs further research to understand inter-individual variability, particularly as calf literature has linked it to solid feed intakes (Neave et al., 2018) and how this impacts the success of gradual weaning strategies (Bittar et al., 2020). Unfortunately, the studies present in this thesis were

unable to collect individualised data on solid feed and water intakes which would have been highly beneficial to the gradual weaning investigation (Chapter 6), as calf evidence shows that gradual weaning does not improve performance for calves with low starter intake at the beginning of the weaning process (Bittar et al., 2020). This lack of individualised data meant links between measures of individuality and solid feeding could not be explored – this should be a priority for future research and could be used to further optimise gradual weaning techniques.

The lack of sufficient consideration of individuals within farming systems (Winckler, 2019) is concerning, and is particularly lacking within the goat industry due to the high number of goat kids produced, each of lower individual economic value than calves and therefore, they are managed at the group-level with a lack of technology being invested in on-farm. The validation of testing methodologies that negate the need for social isolation (such as the group level novel object testing used for calves by (Whalin et al., 2021a) whilst accurately assessing individual responses are key to future individuality research, particularly as welfare relevance would be improved. The sample size needed to accurately assess personality correlation estimates is very high Schönbrodt and Perugini, (2013) proposed a sample size of 250 individuals) and impossible to achieve in one study, therefore multi-study replications with meta analyses should be utilised; the establishment of the 'Many Goats' project should improve research standards in this area and is planning to investigate group-level testing methodologies, however it will be essential that this research consider all ontogenetic stages including juvenile goats.

Farm animal research should become fully invested in the benefits of early-stage participatory engagement and user-centred design which considers both animals and farmers as key stakeholders. Combining classical biological science-based approaches with social science expertise enables research to be tailored to provide solutions that align to stakeholders needs (Weary et al., 2017). For example, Santman-Berends et al., (2014) utilised a multifactorial approach to understand calf mortality, combining the skills of a sociologist alongside a veterinarian to tailor farmer communication which resulted in reduced calf mortality. Similar collaborative mixed-methodology approaches should be the gold standard for applied research; therefore, it is recommended that animal science researchers should ensure this is an integral part of their approach to future goat research. Those reviewing funding applications should be encouraged to look favourably upon proposals that have explicitly considered this, and question those that neglect to mention the importance of understanding on-farm management and farmers views. Whilst research findings are critical to the implementation of high-welfare practices, farmers appear to have difficulty accessing and understanding them (Alarcon et al., 2014), therefore the dissemination of knowledge is worthy of greater research consideration and in particular 'Codes of practice' should be considered a key area for

communication of recommended higher welfare practices. An increase in research conducted using mixed-methodology and participatory engagement approaches should improve the uptake of findings, particularly if combined with an increased availability of scientific literature. The University of Reading's open access fund enabled four of this thesis' chapters to be published open access – there appears to be a growing appetite of farmers and farming adjacent advisors who may not have university credentials (that allow them to access academic journals) who wish to gain information from research studies; all researchers should be encouraged to ensure their findings are freely and widely available wherever possible.

Animal welfare is an ethical and social concern integral to sustainable agriculture (Buller et al., 2018) and to ensure the longevity of the dairy industry it is essential that management is acceptable to the majority of the public (Ventura et al., 2013) who are focusing increasing attention on welfare (Weary et al., 2017). The dairy goat industry has been affected, with an expose of hidden filming by 'Animal Justice' published in British newspapers (Dalton, 2022). Public scrutiny often leads to a 'closed-door' approach (Weary et al., 2017) and at times made communication with, and access to goat farmers for the purposes of this thesis extremely difficult yet hiding farming practices may contribute to a loss in public trust, therefore sustained engagement focusing on providing 'a good life' should be the future direction (Weary et al., 2017). Therefore, goat farmers should be better supported to work with researchers, particularly in multidisciplinary research approaches including early-stage participatory engagement; this should focus on ensuring increased scientific knowledge on the most welfare friendly ways of rearing kids, alongside using social science to understand societal concerns, including the opinions of producers and consumers as equal stakeholders.

The general public are particularly concerned about the concept of 'natural living' (Beaver et al., 2019; Weary et al., 2017), therefore mother-offspring separation is under considerable scrutiny and cow-calf dairying is gaining increasing amounts of recent attention (Johnsen et al., 2021; Neave et al., 2022; Wenker et al., 2021). There are dairy goat farms utilising 'kid at foot' systems and whilst most are smaller scale there was (until recent retirement) a large commercial dairy herd employing this practice, and considerable data could be generated from these farmers using social science techniques. Welfare scientists should welcome the focus on extended mother-offspring contact as a means to increase the ethical acceptability of dairy farming as it has the potential to be highly beneficial to welfare, therefore the extension of this to dairy goat systems should be supported. However, the industry transformation necessary to enable these systems, the likely farmer resistance that would be encountered, and the huge role economics plays must not be underestimated hence this thesis focused on improving the welfare of systems currently used.

There is a distinct lack of baseline data that enables us to fully understand goat kid behaviour and therefore establishing a baseline of what is ‘normal’ behavioural development under naturalistic settings where kids are raised alongside their dams should be a priority area for future research. For an example of how this kind of research can be used to inform on-farm management of artificially reared animals see Cantor et al., (2019) and Whalin et al., (2021b) for reviews of calf literature; this is especially important as ‘natural living’ is an integral part of animal welfare (Fraser et al., 1997). Throughout this thesis research published for the dairy cow industry has had to be drawn upon, and therefore an increase in goat-specific research should be a priority. Overall, more species-specific evidence is needed to guide farmers’ management decisions, and research should aim to provide clear, practical, relevant information that enables them to make well-informed decisions about animal management. Obtaining the knowledge proposed as needed within this section would enhance our ability to employ management changes on dairy goat farms to protect and improve the welfare of the kids, which would ensure consumer confidence as increasing pressure is put onto farm transparency and communication with the public.

8.6 Final conclusions

This research aimed to investigate the systems, behaviour, productivity, individuality (and consequently welfare) of artificially reared goat kids, during the milk feeding period and weaning transition, to provide an evidence base from which to make recommendations for improving on-farm management and further species-specific research. It is clear from recent research and surveys that goat numbers will continue to rise, and that the species will become increasingly important in relation to food security and sustainability. With the concurrent rise in intensive management practices the number of goat kids artificially reared is also likely to increase and therefore this small ruminant is deserving of greater research attention, particularly with consideration given to early-life management practices and welfare. This thesis contributes to filling several key knowledge gaps relating to this area by quantifying how goat kids are currently reared, how willing farmers are to change current rearing practices, and identifying common barriers to the uptake of different management strategies. This knowledge base enabled animal studies to be tailored to provide further understanding of common commercial management techniques, and as abrupt weaning from ad libitum milk feeding was a key welfare concern, a feasible method of gradual weaning was trialled and found to be beneficial to kid welfare. Goat kid individuality has been explored and ways to assess this have been trialled in order to make recommendations that can influence future research methodologies to ensure validity. Whilst the generalisability of the animal studies here is limited by their smaller-scale nature and reliance predominately on male mixed dairy breed kids, they provide new insight into the behaviour and welfare of goat kids that are artificially reared and is a valuable platform to

build on. The knowledge provided by this thesis establishes an essential species-specific baseline that will support recommendations for management change and enable effective research to be planned, funded and implemented in the future.

8.7 References

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Appendix 1: The farmer survey

My name is Holly Vickery and I am a PhD student at the University of Reading. This survey forms part of my thesis which will contribute to my doctorate degree.

About my research:
My research is looking at how we can improve the way we artificially rear goat kids with a focus on milk feeding and weaning methods. It is important to me that my research can be used to inform practice on farm and is therefore essential that results are feasible for farmers to implement. The aim of this questionnaire is to understand what practices are currently being used on farm and identify areas in which changes could be made.

The results from this study will be used as part of my thesis research and may be published as a report in a scientific journal. The survey is anonymous and no individuals will be identified.

What is involved?
This questionnaire consists of 5 sections and should take approximately 15-20 minutes of your time to complete. I am interested in what you are currently doing on your farm and how you might be willing to change this in the future; there are no right or wrong answers.
Once you have completed the survey, you will not be required to do anything else.

How have I been selected?
You may have received this survey if you have attended a GVS or MGA meeting, are members of a goat society, or have found it shared on social media. Only farmers that are artificially rearing goat kids in the United Kingdom are able to participate in this survey.

Confidentiality, storage and disposal of information:
Your name and email address will only be collected if you choose to enter it so you can receive a summary of the results of the survey. They will be removed from your individual response and held in a separate password-protected file which only myself and my supervisor will have access to. These details will not be shared with third parties and will not be published as part of my research.

Data from the survey will be fully anonymous and stored in a password protected file. The data will be securely stored until published in a scientific journal (approx. 2-3 years).

Do I have to take part?
Your participation is entirely voluntary. You do not have to take part in this survey and you are free to exit the survey at any point. Incomplete survey data will not be used for analysis. Once you hand in the paper version or click ‘’submit’’ online your responses will be entered and as

they will be anonymised it will not be possible to withdraw them.

Consent

If you decide to take part in the survey you are acknowledging that you understand the terms of participation as described above and that you consent to them.

Further information and contact details

If at any stage you wish to receive further information about the project please contact me by email. I welcome questions or comments about my research and would also be interested in hearing from farmers who might be interested in participating in future trials.

I very much appreciate your time in reading this and hope you will be able to complete my survey.

Holly Vickery
Email h.m.vickery@reading.ac.uk
School of Agriculture Policy and Development
The University of Reading

Alternatively, you can contact my supervisor:

Dr Rachael Neal
Email r.a.neal@reading.ac.uk
Address: School of Agriculture, Policy and Development, University of Reading, Whiteknights, Reading, United Kingdom, RG6 6AR

This application has been reviewed according to the procedures specified by the University of Reading Research Ethics Committee and has been given a favourable ethical opinion for conduct.

Please tick this box to indicate your consent to participate in this study

If you would be interested in receiving a summary of the project results, please put your name and email address in the box below.

Section A. Background information

The questions in this section are designed to collect information on the kids you are rearing.

A1. How many kids (approximately) are you artificially rearing each year?

Please circle the most appropriate answer.

<20	20-50	50-100	100-200	200-400	400-600	>600

A2. Were these kids bred on your own premises or brought in?

Please circle the most appropriate answer: Bred; Brought in

If brought in, what age are the kids when they arrive on your holding?

A3. Approximately what percentage of the kids you rear are female?

Please circle the most appropriate answer:

100% 80% 50% 20% 0%

A4. If rearing female kids - for what purpose are you rearing them?

Please circle all relevant answers: Milking/breeding; Meat; Other (Please explain)

A5. If rearing male kids - for what purpose are you rearing them?

Please circle all relevant answers: Breeding; Meat; Other (Please explain)

Section B: Milk feeding strategies

The questions in this section are designed to collect information on how you feed milk to artificially reared kids.

B1. After colostrum feeding what kind of milk feeding system are your kids introduced to?

Please circle the most appropriate answer:

Ad libitum feeder (Go to the next question then skip B3)

Bottle feeding (Skip to Question B3)

Other – Please explain below (then skip to Section C: Feeding management)

B2. Ad libitum milk feeder

How many kids do you have per ad libitum teat?

What kind of ad libitum milk feeder are you using (please include make and model if known)?

What temperature is your milk feeder set at (if it changes with age please clarify)?

B3. Bottle feeding

If bottle feeding, how many times per day do you feed the kids (if it changes with age please clarify)?

What quantity of milk do you feed at each time (if it changes with age please clarify)?

Section C: Feeding management

This section is designed to collect information on how you manage the weaning transition of artificially reared kids.

C1. What kind of solid feed do you first introduce the kids to (please include the manufacturers name if known)?

At what age do you introduce this feed?

C2. What kind of forage do you first introduce the kids to?

Please circle all relevant answers: Hay; Haylage; Silage; Straw; Other (please explain)

At what age do you introduce this forage?

C3. Does this diet stay the same throughout the milk feeding period?

Please circle the most appropriate answer: Yes; No
If 'No' please explain any changes below.

C4. When the kids are weaned does this diet stay the same?

Please circle the most appropriate answer: Yes; No
If 'No' please explain any changes below.

Section D: Weaning management

This section is designed to collect information on how you manage the weaning transition of artificially reared kids.

D1. Do you have a target weaning age?

Please circle the most appropriate answer: Yes; No

If ‘Yes’ please state the age below.

D2. Do you have a target weaning weight?

Please circle the most appropriate answer: Yes; No

If ‘Yes’ please state the weight below.

D3. How do you wean your kids?

Please circle the most appropriate answer:

Abrupt weaning (complete and sudden removal of access to milk at the target weight/age) Skip to Part E1 if ad libitum milk feeding – Skip to Part E2 if bottle feeding.

Gradual weaning (incremental weaning based on a series of stages) Please go to Question D4.

Other – Please explain below. Skip to E3

D4. If Gradually weaning please could you describe your process below, including the ages at which it begins & changes?

Section E: Changing management practices for rearing and weaning kids

This section is designed to collect information on how willing you would be to change your current management practices and which changes would be most appropriate to implement on farm.

E1. Questions for those that currently <u>abruptly wean from an ad libitum milk feeder</u>:

On a scale of 1 (Highly unwilling) to 7 (Highly willing), how willing would you be to change to the following gradual weaning methods?

Please circle the most appropriate answer.

Removal of ad libitum teats for a set period of hours per day

Highly unwilling			Neither unwilling or willing			Highly willing
1	2	3	4	5	6	7

Reduction of milk temperature to cold

Highly unwilling			Neither unwilling or willing			Highly willing
1	2	3	4	5	6	7

Decreasing the ratio of milk powder to water

Highly unwilling			Neither unwilling or willing			Highly willing
1	2	3	4	5	6	7

If you have indicated that you are unwilling to implement any of these gradual weaning methods, please use the box below to explain the reasons why

E2. Questions for those that currently <u>abruptly wean from bottle feeding</u>:

On a scale of 1 (Highly unwilling) to 7 (Highly willing), how likely would you be to change to the following gradual weaning methods?

Please circle the most appropriate answer.

Reducing the number of bottle feeds per day

Highly unwilling			Neither unwilling or willing			Highly willing
1	2	3	4	5	6	7

Reducing the amount of milk in each feed

Highly unwilling			Neither unwilling or willing			Highly willing
1	2	3	4	5	6	7

Decreasing the ratio of milk powder to water

Highly unwilling			Neither unwilling or			Highly willing

			willing			
1	2	3	4	5	6	7

If you have indicated that you are unwilling to implement any of these gradual weaning methods, please use the box below to explain the reasons why

Environmental enrichment

For the purposes of this questionnaire, environmental enrichment is defined as any item(s) or stimuli that you have provided beyond what is standard, with the aim of improving the welfare (that is, the physical or psychological well-being) of your kids.

E3. Do you provide your kids with any items you identify as enrichment?

Please circle the most appropriate answer: Yes; No

If 'Yes' please describe the item/s below

E4. On a scale of 1 (Highly unwilling) to 10 (Highly willing), how willing would you be to supply the following enrichment items:

Please circle the most appropriate answer.

An object that allows the kids to climb on top of it - such as a table or straw bale

Highly unwilling			Neither unwilling or willing			Highly willing
1	2	3	4	5	6	7

Swinging items, such as hay nets or hanging balls

Highly unwilling			Neither unwilling or willing			Highly willing
1	2	3	4	5	6	7

Loose items within the pen, such as a large ball

Highly unwilling			Neither unwilling or willing			Highly willing
1	2	3	4	5	6	7

If you have indicated that you are unwilling to provide enrichment items, please use the box below to explain the reasons why

Barriers to the uptake of new management practices:

E5. On a scale of 1 (Highly unimportant) to 10 (Highly important), how important are the following factors to you, when deciding whether to implement a new management practice:

Please circle the most appropriate answer.

The amount of labour and time required to implement the new practices

Highly unimportant			Neither unimportant or important			Highly important
1	2	3	4	5	6	7

The cost required to implement the new practices

Highly unimportant			Neither unimportant or important			Highly important
1	2	3	4	5	6	7

The amount of scientific evidence that the change will be beneficial to the welfare of the kids

Highly unimportant			Neither unimportant or important			Highly important
1	2	3	4	5	6	7

The amount of scientific evidence that the change will be beneficial to the health of the kids

Highly unimportant			Neither unimportant or important			Highly important
1	2	3	4	5	6	7

The amount of scientific evidence that the change will be beneficial to the growth rates of the kids

Highly unimportant			Neither unimportant or important			Highly important
1	2	3	4	5	6	7

If you have any other comments to make on barriers to changing management practices, please make them in the box below