

# *Effect of different storage conditions on analytical and sensory quality of thermally processed milk based germinated Foxtail millet porridge*

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1     **Effect of different storage conditions on analytical and sensory quality of thermally**  
2                     **processed milk based germinated Foxtail millet porridge**

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13    **Abstract**

14    Foxtail millet porridge was prepared using germinated grains and milk and was evaluated for  
15    its storage stability after thermal processing at Ultra High Temperatures (UHT) of 142 °C for  
16    5 s and Retort processing temperatures of 121.5 °C for 15 min. Various physical, chemical  
17    and microbial changes of the porridge were studied for a storage period of 180 days at 25 ± 1  
18    °C. Using consumer perception and survival analysis, the predicted shelf life of the UHT  
19    treated and retort processed foxtail millet porridge samples stored at 25 ± 1 °C was found to  
20    be 186 ± 9 days and 245 ± 15 days, respectively. Also, data from consumer liking, profiling,  
21    physical, chemical and microbial parameters showed significant changes ( $p < 0.05$ ) in the  
22    thermally treated packaged porridge samples over time. As the consumer overall acceptability  
23    decreased, the detection of positive attributes (Thick and uniformly coloured texture and  
24    appearance; grainy mouth texture; caramel taste and aroma) in the porridge decreased, while  
25    the detection of negative attributes (Uneven, decoloured, and curdled texture and appearance;

26 sticky mouth texture; cooked, sour and off smell; cooked, sour and off taste) increased. The  
27 present study could establish a significant difference ( $p < 0.05$ ) in the storage induced  
28 properties of UHT and retort processed porridge samples. The analytical evaluation of foxtail  
29 millet porridge found that UHT treated porridge was better in quality, but consumers  
30 preferred retort processed porridge.

31 **Keywords:** Foxtail millet porridge, retort processing, UHT, survival analysis, CATA sensory  
32 analysis

33 **Practical Application:** The quality and sensory attributes, evaluated for UHT treated and  
34 retort processed porridge samples during the storage period of 180 days, were found to be  
35 contradictory. Based on the results of CATA sensory analysis, the shelf life of UHT treated  
36 and retort processed porridge samples was predicted to be more than 6 months. Therefore,  
37 both UHT treatment and retort processing can be effectively applied to prepare a ready to eat  
38 milk based porridge using germinated foxtail millet grains.

## 39 **Introduction**

40 Millet is a commonly consumed crop in the arid and semi-arid tropics. Whole millet  
41 grains are used as an ingredient for developing various food products in Asia and Africa.  
42 Foxtail millet (*Setaria italica* L.) is a minor millet which is usually used for feed formulations  
43 in many parts of the world. However, its minimum requirement of agricultural inputs,  
44 pertinent nutrient composition and health benefitting properties like cancer prevention,  
45 hypoglycaemic and hypolipidemic effects, is now making it an important commodity for  
46 agricultural scientists to research on, especially to combat food insecurity around the world  
47 (Sharma and Niranjana, 2017). As a consequence, developments in agriculture (eg.,  
48 development of high yielding varieties through breeding programs) and food technology (eg.,

49 identification of unit operations for processing) are now being employed to improve the  
50 quality and palatability of foxtail millet foods and to make them more available in the market  
51 for consumption.

52         Though foxtail millets have been shown to provide nutritional security, but their  
53 consumption has been limited due to the presence of some antinutritional effects (Pradeep &  
54 Sreerama, 2015). The literature reports that processing methods like germination can easily  
55 suppress the antinutritional activities and improve the nutritional and functional properties of  
56 these millets (Adebiyi, Obadina, Adebo & Kayitesi, 2018). Sharma, Saxena and Riar (2015)  
57 showed that germination of foxtail millet seeds considerably improved its composition by  
58 increasing the bio-availability of bioactive compounds such as total phenolics, antioxidants,  
59 total flavonoids, dietary fiber, proteins, minerals, and decreasing the anti-nutritional factors  
60 like phytic acid and tannin content.

61         Thermal treatment has been most effectively used as a method of preservation to  
62 extend the shelf life of various liquid food products. Milk based porridge is a common  
63 wholesome breakfast meal consumed in almost all parts of the world. Therefore, efforts are  
64 now being put to prepare a ready to eat breakfast cereal, that requires minimal or no cooking  
65 with maximum retention of nutrients. Apart from this, ready to eat milk based porridges can  
66 also be used as a part of mid day meal programmes for school children in under-developed  
67 and developing nations, thus adding micronutrients to their daily diet. UHT treatment is a  
68 most common practice to improve microbial stability and extend shelf-life of liquid food  
69 products, thus maintaining their consistency throughout its shelf life (Mäkinen et al., 2015).  
70 Although, many studies have widely used retort processing to prepare various ready to eat  
71 milk products (Gautam, Jha, Jafri & Kumar, 2014; Jha, Patel, Gopal & Ravishankar, 2011,  
72 2012), but very limited or no study has reported the significance of UHT treatment for large

73 scale preparation shelf stable ready to eat milk based porridges (Kumar, Harish,  
74 Subramanian, Kumar & Nadanasabapathi, 2017). Therefore, a study was conducted to  
75 prepare a milk based porridge, using germinated foxtail millet grain flour. This porridge was  
76 evaluated for its stability after UHT treatment and retort processing to decide the extent of  
77 thermal treatment required to prepare a ready to eat porridge. Finally, various quality  
78 attributes such as physical, chemical, microbial and sensory parameters were studied for the  
79 foxtail millet porridge during a storage period of 180 days at  $25 \pm 1$  °C to investigate the  
80 effect of thermal treatment on storage stability.

## 81 **Materials and Methods**

### 82 **Formulation of Foxtail millet porridge**

83 Foxtail millet (*Setaria italica* L.) grains obtained from authorized grain centres of  
84 Varanasi (India), was subjected to germination using method as described by Sharma, Goyal,  
85 Alam, Fatma and Niranjan (2018). These germinated grains were then dried to a final  
86 moisture content of 7-8% and milled into fine flour using a Laboratory miller (PERTEN  
87 3100, Huddinge, Sweden) with particle size ranging between 100-200 µm. The foxtail millet  
88 flour obtained after germination was cooked in milk (2% fat; 8.5% SNF) and mixed with  
89 appropriate levels of powdered sugar. Various combinations of foxtail millet flour, milk and  
90 powdered sugar, used to prepare porridge were studied for its sensory characteristics based on  
91 a 9-point Hedonic scale using semi-trained sensory panel (with prior experience of sensory  
92 evaluation of milk based porridge like products) consisting of 10 judges in the age group of  
93 25 – 45 years. This sensory evaluation was done at room temperature ( $25 \pm 2$  °C).

94 To decide the final formulation ratio, overall consumer liking of the porridge samples  
95 was used and out of the various suggested formulations, a ratio of 1:2:1.3 for powdered sugar,

96 milk and germinated foxtail millet flour, respectively, was considered most suitable for the  
97 porridge premix. For preparation of foxtail millet porridge, the milk was heated to  $90 \pm 2$  °C  
98 in a steam jacketed vessel (5 ltr capacity) and appropriate amounts of powdered sugar and  
99 germinated foxtail millet flour was added to it. The temperature of mix was maintained at  $90$   
100  $\pm 2$  °C for 2 min, with gentle and constant stirring during cooking using a mixture emulsifier  
101 for uniform heating and to prevent clump formation. Fresh prepared foxtail millet porridge  
102 was then cooled to  $25 \pm 2$  °C and then subjected to two different types of thermal treatments:  
103 Ultra High Temperatures (UHT) of 142 °C for 5 s and Retort processing temperatures of  
104 121.5 °C for 15 min.

105 The heat-treated foxtail millet porridge samples were packaged in aluminum based  
106 LDPE pouches (250 ml each), with a thickness of 30 gauge. The porridge samples were then  
107 examined and compared for two different heat treatments: UHT treatment and retort  
108 processing. The packaged samples were then stored at  $25 \pm 1$  °C and studied for its shelf life  
109 for a storage period of 180 days.

#### 110 **UHT treatment**

111 For UHT treatment, the freshly prepared foxtail millet porridge was cooled and  
112 treated at ultra-high temperatures of 142 °C for 5 s and packaged in sterilized aluminium  
113 based LDPE pouches in a sterile UV chamber. This was carried out in a heat exchanger  
114 processing unit (Armfield FT74XTS UHT/HTST System, Hampshire, UK) equipped with  
115 standard tubular heat exchanger (FT74-20-MKIII, Hampshire, UK) tubes to maintain the  
116 processing temperature. The porridge sample was added through the feeding tank and inlet,  
117 preheating, processing and cooling temperatures were recorded to be at 42 °C, 94 °C, 142 °C  
118 and 35 °C ( $\pm 2$  °C), respectively, and a pressure of  $5.7 \pm 2$  bar.

## 119 **Retort processing**

120 For retort processing, the freshly prepared porridge was first cooled and then  
121 packaged in aluminium based LDPE pouches and then subjected to thermal treatment at a  
122 temperature of 121.5 °C for a period of 15 min in a pilot-scale horizontal stationary retorting  
123 system (Lakshmi Engineering, Chennai, India), as optimized by Gautam et al. (2014) for  
124 *Chhana kheer*. The steam-air overpressure was maintained at  $20 \pm 2$  °C during the process. In  
125 the end of the process, rapid cooling was done by recirculating cool water at  $27 \pm 2$  °C. A  
126 Cu/CuNi thermocouple (Lakshmi Engineering, Chennai, India) was inserted in three retort  
127 processed pouches containing porridge, in every batch to obtain heat penetration data and  
128 record the process lethality values ( $F_0$ ).

## 129 **Storage-induced changes in the quality of thermally processed foxtail millet porridge**

130 Both UHT treated and retort processed foxtail millet porridge packaged in aluminium  
131 based LDPE pouches were stored at  $25 \pm 1$  °C and  $55 \pm 5\%$  relative humidity (of storage  
132 room) for 180 days. Random samples were withdrawn at 20 days interval during storage and  
133 analysed for changes in various quality attributes.

134 **Viscosity.** Steady shear viscosity of packaged foxtail millet porridge samples was  
135 performed on Bohlin C-VOR 150 rheometer (Malvern Instruments Ltd., Malvern,  
136 Worcestershire, UK) using C25 DIN 53019 coaxial cylinder geometry. Sample flow curves were  
137 recorded in linear progression with shear rate from 10 to 1000  $s^{-1}$  for 120s with isothermal  
138 temperature programming. Flow curves of the samples were obtained by plotting  
139 instantaneous viscosity against respective shear rates. Temperature condition was maintained  
140 strictly at  $25 \pm 1$  °C for measurement since viscosity of a substance changes substantially  
141 with temperature. All measurements were conducted in triplicates. Herschel-Bulkley's model



142 was used to determine consistency ( $K$ ) coefficient and flow behaviour index ( $n$ ) of the stored  
143 porridge samples by modelling the steady state flow curves (Steffe, 1996).

$$144 \quad \sigma = \sigma_0 + K\dot{\gamma}^n \quad (3.23)$$

145 Where,  $\sigma_0$  is the yield stress and  $\dot{\gamma}$  is the shear rate.

146 **pH.** Orion star A111 benchtop pH meter (EW-58825-04, Illinois, US) was used to  
147 determine the pH of packaged foxtail millet porridge samples. Measurement were taken in  
148 triplicates at  $25 \pm 1$  °C.

149 **Whiteness index.** Spectrophotometer ColorLite sph850 (ColorLite GmbH, Katlenburg-  
150 Lindau, Germany) was used for colour measurements of packaged porridge samples and  
151 results were expressed as  $L^*$   $a^*$   $b^*$  coordinates. The CIELAB system consisted of  
152 colorimetric indices  $L^*$  (lightness)  $a^*$  and  $b^*$  (green-red and blue-yellow colorations,  
153 respectively). Whiteness index of porridge was measured at  $25 \pm 1$  °C using following  
154 equation (Loypimai and Moongngarm, 2015).

$$155 \quad \textit{Whiteness Index} = 100 - [(100 - L^*)^2 + (a^*)^2 + (b^*)^2]^{0.5} \quad \dots (3.24)$$

156 Each sample was collected in glass container, measured at 3 different positions and  
157 the average of the values were taken. All the measurements were taken while keeping the  
158 external light and temperature conditions similar to minimise variation in results.

159 **Proteolysis, lipolysis, oxidation and Maillard reaction.** Free amino groups in packaged  
160 foxtail millet porridge samples were determined in terms of trinitrobenzene sulfonic acid  
161 (TNBS) value by the method modified by Spadaro, Draghetta, Del Lama, Camargo and  
162 Greene (1979). Similarly, the free fatty acid (FFA) was estimated using a titration method  
163 suggested by Deeth and Fitz-Gerald (1975).

164 The fat oxidation during storage in the foxtail millet porridge samples was determined  
165 in terms of thiobarbituric acid (TBA) value using the method of Sidwell, Salwin and Mitchell  
166 (1955). Finally, the Maillard reaction in the porridge samples was determined in terms of  
167 hydroxymethylfurfural (HMF) content using the method of Keeney and Bassette (1959).

168 **Microbial changes.** The stored samples were analysed for total plate count, yeast and  
169 mould count and coliform count using plate count agar (PCA), potato dextrose agar (PDA)  
170 and violet red bile agar (VRBA), respectively. The presence or absence *Clostridium*  
171 *botulinum*, *Salmonella sp* and *Staphylococcus aureus* was confirmed using reinforced  
172 clostridial agar, bismulth sulphite agar and mannitol salt agar, respectively for standard plate  
173 count method. An ethical committee then monitored the microbial changes to ensure its  
174 safety to be consumed.

## 175 **Shelf life evaluation**

176 **Sensory evaluation.** To carry out sensory tests, the ethical committee considered the  
177 following limit values for acceptable porridge life: pH between 6.6 to 7.0 and total bacterial  
178 count less than 30,000 CFU ml<sup>-1</sup>. Regular porridge consuming individuals (n=100, 48 males  
179 and 52 females in age group 25 – 45 years) were recruited and presented with 9 UHT treated  
180 and 9 retort processed samples stored for different time periods at 25 ± 1 °C (0, 20, 40, 60,  
181 80, 100, 120, 140, 160 and 180 days). Total number of samples were randomized and divided

182 into two batches for each treatment to avoid fatigue of the panellists. For each treatment, two  
183 sensory sessions were carried out in a day and the panellists were required to compare five  
184 samples at a time. For example, in the first session samples stored from 0 to 80 days were  
185 compared, while in the second session samples stored at 100 to 180 days were compared.  
186 Similar methods were applied to prepare porridge samples at different time intervals such that  
187 the samples for all the storage times were ready on the day of sensory evaluation. The method  
188 of sensory analysis was followed as described by Richards, Buys and De Kock (2016).

189 The consumer study was carried out using the following procedure:

- 190 1) Consumers were asked for their porridge eating patterns and were selected if they  
191 consumed any milk/cereal-based porridge at least thrice a week.
- 192 2) The individuals were asked if they would normally buy this product from the market  
193 and consume it. They were asked to answer in “yes” or “no”.
- 194 3) The consumers were then asked to rate the samples based on its appearance,  
195 consistency, taste, aroma, flavour and overall liking on a 9 point hedonic scale (1  
196 being “dislike extremely” and 9 being “like extremely”) and the final overall liking  
197 score was used to rate thermally treated porridge samples.
- 198 4) Finally, they were asked to give a sensory profile of the samples based on a list of  
199 check-all-that-apply (CATA) sensory attributes that could appropriately describe the  
200 packaged porridge samples. Following were the 15 quality attributes: Visual texture  
201 and appearance- thick, unevenness, uniform colour, discoloration, curdling; In mouth  
202 texture- grainy, sticky; Smell: caramel, cooked, sour, off; Taste: caramel, cooked,  
203 sour, off.

204 The sensory evaluation was done manually using proformas comprising of 9 point  
205 hedonic scales and CATA questions. The panellists were explained about the nature of  
206 experiments without disclosing the identity of samples. They were required to fill up the form  
207 while evaluating the sample in isolated environments on separate tables at room temperatures  
208 and were not allowed to make any changes thereafter. Filtered water was provided to the  
209 consumers to neutralize and clean their palate before and in between sample tasting.

210 **Survival analysis.** Survival analysis was used to estimate the shelf life of the UHT treated  
211 and retort processed foxtail millet porridge samples using the results obtained from  
212 consumers when asked if they would normally consume the foxtail millet porridge stored at  
213  $25 \pm 1$  °C for a time period of 180 days (Hough, Langohr, Gómez, & Curia, 2003; Gambaro,  
214 Fiszman, Giménez, Varela & Salvador, 2004a; Gambaro, Gimenez, Varela, Garitta & Hough,  
215 2004b; Gambaro, Ares & Gimenez, 2006). The methodology is primarily focused on the shelf  
216 life hazard on the consumer rejecting the product and not on the product deterioration.  
217 Discrete statistical distribution (Weibull, logistic, Gaussian, log-logistic and exponential)  
218 were fitted to the data obtained in the consumer test and the best fit (obtained by a visual  
219 inspection of the curves) was used to express  $F(t)$  (Richards et al., 2016).

220 Finally, the shelf life of the packaged foxtail millet porridge was obtained by  
221 substituting the parameters found in the previous fit followed by considering 25 and 50%  
222 consumer rejection (Hough et al., 2003; Gambaro et al., 2006; Gimenez et al., 2007; Cruz et  
223 al., 2010).

## 224 **Statistical analyses**

225 The score of all the sensory attributes and the results obtained from each set of experiments  
226 were analysed statistically using one-way analysis of variance (ANOVA) to find the

227 significance of variation in the data obtained and the mean of triplicate experimental values  
228 along with their standard deviations were reported. The difference among the experimental  
229 treatments was determined using least significant difference (LSD). Minitab 17.0 software  
230 was used for the analysis with a statistical significance set at  $p < 0.05$ .

## 231 **Results and Discussion**

### 232 **Quality evaluation of UHT treated and retort processed Foxtail millet porridge**

233 The heat-treated foxtail millet porridge samples were packaged in aluminum based  
234 LDPE pouches. The packaged samples were then stored at  $25 \pm 1$  °C and studied for its shelf  
235 life for a storage period of 180 days. Following quality attributes of the porridge samples  
236 were studied during storage.

237 **Viscosity.** The foxtail millet porridge samples treated under UHT temperatures and retort  
238 processing temperatures adequately fitted the Herschel-Bulkley's model at  $25 \pm 1$  °C and  
239 were found to exhibit pseudoplastic behavior. The viscosity increased from 3.935 to 4.490  
240 mPa.s and 4.610 to 5.211 mPa.s after 180 days of storage at  $25 \pm 1$  °C for UHT treated and  
241 retort processed samples, respectively (Figure 1-a). The difference in the viscosity values  
242 between both samples revealed that UHT treatment of the porridge did not significantly  
243 increased the viscosity of the porridge, as compared to retort processing. For, both the  
244 treatments (UHT and retort), the samples showed a significant change ( $p < 0.05$ ) in its  
245 viscosity only after 80 days of storage. Since the viscosity values remained below 10 mPa.s,  
246 so there were no signs of clotting or gelation (Kocak and Zadow, 1985). This age thickening  
247 could be due to structural rearrangements caused due to thermal process induced changes in  
248 casein micelles, proteins and fat globules. Storage of thermally processed porridge also  
249 causes modifications like aggregation, denaturation, polymerization, etc. in the continuous

250 phase by increasing the volume of the dispersed components (Ranalli, Andrés & Califano,  
251 2017). These results were in agreement with the findings of Abdulghani, Prakash, Ali and  
252 Deeth (2015) for UHT milk fortified with iron, magnesium and zinc.

253 In addition to this, as characterized in Table 1, the yield stress ( $\sigma_0$ ) increased  
254 significantly ( $p < 0.05$ ) after 80 days and then decreased after 160 days of storage for UHT  
255 treated samples, while  $\sigma_0$  increased significantly ( $p < 0.05$ ) after 60 days of storage and  
256 decreased after 160 days of storage for retort processed samples. Consistency coefficient ( $K$ )  
257 significantly ( $p < 0.05$ ) increased between 80 to 140 days of storage. However, the flow  
258 consistency index ( $n$ ) remained unaffected throughout the storage period. This behavior of  
259 the Herschel-Bulkley's equation parameters, were also studied by Ranalli et al. (2017), who  
260 quoted similar results for a milk product, *Dulce de leche*-like product enriched with  
261 emulsified pecan oil. Higher values of  $\sigma_0$  and  $K$  for retort processed foxtail millet porridge  
262 samples as compared to the UHT treated foxtail millet porridge samples could be due to  
263 intense thermal treatment of the porridge in case of retort processing. Fermented finger millet  
264 thin porridge was also found to have higher values of  $\sigma_0$  and  $K$  with the increase in the  
265 intensity of the thermal treatment (Ojijo & Shimoni, 2004). These changes in the rheology of  
266 porridge has been explained by Datta and Deeth (2001) in terms of weakening of milk protein  
267 structure because of the proteolytic breakdown by microorganisms.

268 **pH.** The pH of the porridge samples dropped from an initial average value of 7.00 to 6.64  
269 and 6.78 to 6.60 after a storage period of 180 days at  $25 \pm 1$  °C for UHT treated and retort  
270 processed samples, respectively (Figure 1-b). Similar type of reduction in pH values for milk  
271 with storage was explained by Gaucher, Mollé, Gagnaire and Gaucheron (2008), stating  
272 precipitation of calcium phosphate, dephosphorylation of casein, breakdown of lactose, or  
273 proteolysis, as one of reasons. The difference in the values of pH for UHT treated and retort

274 processed samples could be due to the use of different temperatures for the treatment of  
275 porridge samples. The fact that higher processing temperatures can lead to a higher pH was  
276 also established by Zamberlin and Samaržija (2017) for different heat treatments given to  
277 sheep's milk.

278 **Whiteness index.** The whiteness index of UHT treated porridge varied significantly ( $p <$   
279  $0.05$ ) with the retort processed porridge, whereas, only a slight decrease in the whiteness  
280 index was observed in its values during the storage period of 180 days at  $25 \pm 1$  °C (Figure 1-  
281 c). A whiteness index value of 59.39 (a.u.) was calculated for UHT treated porridge and  
282 56.64 (a.u.) for retort processed porridge, which was found to decrease to 55.60 (a.u.) and  
283 48.63 (a.u.), respectively, with storage at  $25 \pm 1$  °C for 180 days. This clearly stated that high  
284 temperature treatment for longer time periods caused browning of the foxtail millet porridge  
285 as compared to the high temperature treatment for shorter time periods, which was in  
286 agreement with the studies done by Srikaeo, Furst, Hosken and Ashton (2005). Slight change  
287 in the colour of semi-skimmed UHT milk with storage was also observed by Gaucher et al.  
288 (2008).

289 Cooking of grains causes gelatinisation of starch present in them, thus imparted  
290 higher  $a^*$  (redness) and  $b^*$  (yellowness) values to high temperature treated porridge (data not  
291 shown). Another factor that could have affected the whiteness index of the porridge is the  
292 Maillard reaction taking place in the milk during heating. Intensive heat treatment for longer  
293 times causes formation of brown pigments called melanoidins from reducing sugars and  
294 proteins present in the milk (Van Boekel, 1998). Apart from this, proteolysis of the milk  
295 product during storage could also be a reason that affects the whiteness of milk as it results in  
296 the formation of aggregates that causes browning (Jensen et al., 2015).

297 **Chemical reactions.** Most of the microorganisms get inactivated by thermal treatment, but  
298 still there are some heat-resistant enzymes of native and bacterial origin that survive high  
299 temperatures and causes flavour and textural defects in milk and milk based porridges (Datta,  
300 Elliott, Perkins & Deeth, 2002). Proteolysis of high temperature treated milk and milk  
301 products during storage at room temperature is one of the major factors limiting its shelf life  
302 due to the changes in texture and flavor (Datta et al., 2002). Proteolysis causes formation of  
303 off-flavours in milk due to the release of tyrosine and the textural changes are due to age  
304 gelation due to formation of complexes on hydrolysis of caseins (Richards et al., 2016).  
305 The level of proteolysis, measured in terms of TNBS value, of packaged foxtail millet  
306 porridge samples at  $25 \pm 1$  °C increased at a slow rate for upto a storage period of 80 days for  
307 UHT treated porridge and 60 days for retort processed porridge and soon after this, it  
308 increased at a higher rate (Figure 2-a). The TNBS values increased from 0.847 to 2.880  $\mu\text{mol}$   
309  $\text{ml}^{-1}$  and 0.885 to 2.962  $\mu\text{mol ml}^{-1}$  for UHT treated and retort processed samples,  
310 respectively. No significant change was observed for TNBS values of both thermal  
311 treatments. This study complied with the findings of El-Din, Aoki and Kako (1991) and  
312 Gaucher et al. (2008), who observed an increase in non-casein nitrogen and non-protein  
313 nitrogen in UHT treated milk due to proteolysis caused with storage.

314 Thiobarbituric acid (TBA) reactive substances is a measure of the formation of  
315 secondary oxidation products such as carbonyls. Lipid present in milk may undergo chemical  
316 and physical changes such as autoxidation and formation of trans fatty acids during  
317 processing and storage which leads to production of low molecular weight compounds  
318 (aldehydes, ketones and lactones) with losses in sensory quality (Semma, 2002). High  
319 temperatures (above 100 °C) treatment of milk or milk based products are found to be rich in  
320 polyunsaturated fatty acids, so they contribute to the start of oxidation reactions (Datta et al.,  
321 2002; Kurniadi et al., 2017). Therefore, a significant ( $p < 0.05$ ) increase in oxidation was



322 observed for packaged foxtail millet porridge stored at  $25 \pm 1$  °C for 180 days (Figure 2-b).  
323 The TBA values increased from 0.045 to 0.098 and 0.066 to 0.113 as absorbance at 532 nm  
324 for UHT treated and retort processed porridge samples, respectively. Similar observation  
325 were made by Gautam et al. (2014) for *chhana kheer* and Ranalli et al. (2017) for *Dulce de*  
326 *leche*-like product enriched with emulsified pecan oil.

327 HMF is formed as a result of progression of Maillard reactions and it increased with  
328 the increase in the storage time (Jha et al., 2012). If the heat treatment is applied to milk and  
329 milk products, HMF is formed due to isomerisation and subsequent degradation of sugars  
330 (Morales & Jiménez-Pérez, 1998; Bunkar, Jha, Mahajan & Unnikrishnan, 2014). The HMF  
331 content increased from 18.34 to 59.44  $\mu\text{mol ml}^{-1}$  and 25.82 to 66.38  $\mu\text{mol ml}^{-1}$  at  $25 \pm 1$  °C  
332 during a storage period of 180 days for UHT treated and retort processed porridge samples,  
333 respectively (Figure 2-c). Higher HMF values in retort packaged samples could be due to  
334 application of high temperatures for longer times.

335 Free fatty acid is an indicator of oxidative degradation of lipids present in the milk  
336 products. During storage, lipid in food products is readily hydrolyzed by enzymes such as  
337 lipases (Clayton & Morrison, 1972). However, lipases are denatured during thermal  
338 processing, therefore, it is hypothesized that the increase in FFA content in stored products  
339 could be a result of decomposition of hydroperoxide (Thakur and Arya, 1990; Khan, Semwal,  
340 Sharma & Bawa, 2014). Figure 2-d depicts an increase in the FFA content from 2.34 to 3.21  
341  $\mu\text{eq. l}^{-1}$  for UHT treated porridge samples and 2.87 to 3.38  $\mu\text{eq. l}^{-1}$  for retort processed  
342 porridge samples during storage upto 180 days, thus evaluating the extent of lipolysis in  
343 foxtail millet porridge samples. Gautam et al. (2014) explained the increase in lipolysis  
344 during storage of *chhana kheer* due to the release of free fatty acids during heat treatment and  
345 the presence of high moisture content. While the increase in maillard browning was attributed

346 to the conversion of sulfhydryl (-SH) groups to disulphide (S-S) groups in the presence of  
347 oxygen. Difference in the values of FFA for both the thermal treatments was also observed,  
348 which could be attributed to the high temperature treatment for longer times in retort  
349 processing and shorter times in UHT treatment.

350 **Microbial changes.** The packaged foxtail millet porridge samples stored at  $25 \pm 1$  °C were  
351 subjected to microbial analysis to ensure it is safe to consume for sensory analysis. Table 2  
352 characterizes the data obtained from microbial analysis for UHT treated and retort processed  
353 porridge samples for the storage period of 180 days at  $25 \pm 1$  °C. It was observed that the  
354 total plate count and yeasts and molds count for samples packaged after UHT treatment and  
355 stored at  $25 \pm 1$  °C showed a slightly higher microbial load as compared to the retort  
356 processed samples stored at  $25 \pm 1$  °C for the total storage period of 180 days. This could be  
357 either due to the different time-temperature combinations for both heat treatments, or due to  
358 ineffective handling of the product while packaging. However, no significant difference was  
359 observed in the microbial quality. No coliforms and organisms such as *Clostridium*  
360 *botulinum*, *Salmonella spp.* and *Staphylococcus aureus* were detected in the samples. In view  
361 of the pH and microbiological results, the ethical committee decided that all the samples were  
362 adequate for sensory tests by humans.

### 363 **Consumer perception and shelf life modelling**

364 **Changes in the consumer overall acceptability and CATA analysis.** Based on  
365 statistical analysis, it was found that the overall liking scores from the consumers  
366 significantly decreased with the progression of the storage period at  $25 \pm 1$  °C ( $p < 0.05$ ). A  
367 linear correlation ( $r^2 = 0.98$ ) was found between the overall acceptability scores (obtained  
368 from the consumers' panel) and the storage time. Hough et al. (2002) suggested  
369 determination of shelf life with identifying the first significant ( $p < 0.05$ ) negative change in

370 the overall acceptability of the product. As can be seen from Figure 3-a, the overall  
371 acceptability significantly ( $p < 0.05$ ) changed with progression of the storage period.

372 Consumers checked all 15 sensory attributes to describe both thermally processed  
373 porridge samples as they were presented to them during their storage. The frequency of each  
374 sensory attribute in CATA question that has been used to for the porridge samples are  
375 presented in Table 3 and 4. Amongst the 15 sensory attributes, 5 positive attributes (Thick  
376 and uniformly coloured texture and appearance; grainy mouth texture; caramel taste and  
377 aroma) were found to have significantly ( $p < 0.05$ ) different frequencies for both the porridge  
378 samples. This analysis also indicated that the sensory quality of porridge samples deteriorated  
379 with time. Similar results were observed by Bruzzone et al. (2015) for milk desserts; Farah,  
380 Araujo and Melo (2016) for yoghurts', whey-based beverages' and fermented milks'; Richards  
381 et al. (2016) for low-fat UHT milk; Oliveira et al. (2017) for non-fermented probiotic milk  
382 and Antúnez, Vidal, Saldamando, Giménez and Ares (2017) for powdered drinks.

383 **Survival analysis.** For the consumer sensory data of both UHT treated and retort  
384 processed foxtail millet porridge, following standard distribution were compared for log-  
385 likelihood: Weibull, logistic, Gaussian, log-logistic and exponential. Table 5 revealed that the  
386 log-likelihood values was least for the Weibull distribution, thus showing best fit for the  
387 survival analysis of the sensory data. Therefore, the Weibull distribution was selected to  
388 model the rejection of packaged foxtail millet porridge samples at  $25 \pm 1$  °C. Many studies in  
389 shelf life determination used Weibull distribution for shelf life modelling of milk products  
390 such as probiotic milk (Oliveira et al., 2017); nutricereal based fermented baby food (Rasane,  
391 Jha & Sharma, 2015); yogurt (Karagül-Yuceer, Coggins, Wilson & White, 1999; Curia,  
392 Aguerriido, Langohr & Hough, 2005; Cruz et al., 2010).

393 The rejection function ( $F(t)$ ) plot was determined as shown in Figure 3-b. To predict a  
394 shelf life, the probability of a consumer rejecting the product i.e.,  $F(t)$ , needs to be selected.  
395 Several studies on shelf life predication modelling used 25 % rejection (Gambaro et al.  
396 2004a, 2004b), while some other used 50 % rejection to estimate the shelf life (Gacula &  
397 Singh, 1984; Cardelli & Labuza, 2001). Thus, over the time both 25 and 50 % rejection were  
398 considered in number of studies (Gambaro et al., 2006; Araneda, Hough & De Penna, 2008;  
399 Cruz et al., 2010). Therefore, in the present study, the shelf life of the packaged porridge  
400 samples was determined at 50 % consumer rejection.

401 Amongst both thermal treatments, UHT treated samples were the first to be rejected  
402 by the consumers. The first rejection score for UHT treated porridge samples was obtained at  
403 day 80 after which the rejection probability accelerated significantly, thus rendering the  
404 samples unacceptable by 25% consumer on day 122 (Figure 3-b), as described by Labuza and  
405 Schmidl (1988). While, for retort processed samples, first rejection was obtained at day 140,  
406 which accelerated after day 160 (Figure 3-b), with a highest rejection score on day 180  
407 resulting in the end of the study.

408 The predicted shelf life of the UHT treated foxtail millet porridge samples stored at 25  
409  $\pm 1$  °C was found to be 186 days with lower and upper confidence levels of 177 and 195 days.  
410 While, for retort processed porridge samples it was found to be 245 days with lower and  
411 upper confidence levels of 230 and 260 days. The difference in the shelf life of foxtail millet  
412 porridge samples packaged under different thermal treatments could be due to change in  
413 product quality due to different heat treatments corresponding to the change in physical and  
414 sensory properties of the products such as colour and appearance, flavor and sweetness, body  
415 and texture and mouthfeel of the product, which ultimately affected the overall acceptability  
416 of the product. The significant ( $p < 0.05$ ) changes in the sensory perception of the consumers

417 justified the degradation of the quality of porridge with storage time due to various physico-  
418 chemical and microbial changes that occurred after processing (Datta et al., 2002) These  
419 results were in agreement with Stoeckel, Lidolt and Hinrichs (2016) and Richards et al.  
420 (2016).

## 421 **Conclusion**

422 In this study, a premix was developed using germinated foxtail millet flour.  
423 According to the overall acceptability, a ratio of 1:2:1.3 was selected for powdered sugar,  
424 milk and germinated foxtail millet flour, respectively, which was then cooked to prepare a  
425 milk based porridge. The main aim of this study was to develop a porridge using this premix  
426 and establish a comparison between the storage induced changes in various physical,  
427 biochemical, microbial and sensory properties of the porridge, thermally processed using  
428 UHT of 142 °C for 5 s and Retort processing temperatures of 121.5 °C for 15 min. The results  
429 showed that retort processing at higher temperatures for a longer time was responsible for  
430 higher values of  $\sigma_0$  and  $K$ ; higher values of pH; formation of brown pigments from reducing  
431 sugars and proteins present in the milk; and higher values of TNBS, TBA, HMF and FFA.  
432 Thus, concluding that the quality of UHT treated porridge samples was better than the retort  
433 processed porridge samples during storage. While, in case of shelf life at a storage  
434 temperature of  $25 \pm 1$  °C, the UHT treated samples were the first to be rejected by the  
435 consumers, thereby limiting its predicted shelf life to 186 days with lower and upper  
436 confidence levels of 177 and 195 days, as compared to the retort processed porridge samples,  
437 whose predicted shelf life was found to be 245 days with lower and upper confidence levels  
438 of 230 and 260 days. Contrasting results were observed between the UHT and retort  
439 processed germinated foxtail millet porridge quality and its consumer acceptance. Though the  
440 quality attributes were found to be better for UHT treated porridge samples during the storage

441 period, but the consumers preferred retort processed porridge samples. Therefore, it was  
442 concluded that the extent of thermal treatment needed to prepare a ready to eat porridge, can  
443 be decided based on its quality as well as consumer preference.

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#### 448 **Author Contributions**

449 Nitya Sharma designed the study, carried out the experiments, interpreted the results  
450 and wrote the research article; Tanweer Alam and S.K. Goyal helped in designing the study  
451 and supervised the research work; Sana Fatma helped in doing the corrections and proof  
452 reading; Sheetaal Pathania helped in carrying out experiments and interpretation of results;  
453 Keshavan Niranjana helped in planning the experiments, interpretation of results and proof  
454 reading of the final research article.

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625 **Table 1** Changes in Hershel-Bulkley parameters of packaged foxtail millet porridge during  
626 storage at 25 °C

Storage time (days)	UHT treated samples			Retort processed samples		
	$\sigma_0^*$	K*	n*	$\sigma_0^*$	K*	n*
	(Pa)	(Pa.s <sup>n</sup> )		(Pa)	(Pa.s <sup>n</sup> )	
0	18.7±1.5 <sup>aA</sup>	1.48±0.07 <sup>a</sup>	0.55	27.5±1.0 <sup>aB</sup>	1.63±0.09 <sup>a</sup>	0.57
20	19.4±1.2 <sup>aA</sup>	1.52±0.03 <sup>a</sup>	0.53	28.8±1.5 <sup>aB</sup>	1.69±0.04 <sup>a</sup>	0.54
40	20.1±1.0 <sup>aA</sup>	1.57±0.02 <sup>a</sup>	0.56	29.6±2.2 <sup>aB</sup>	1.72±0.08 <sup>a</sup>	0.56
60	21.5±1.2 <sup>aA</sup>	1.60±0.05 <sup>a</sup>	0.57	33.0±2.0 <sup>bB</sup>	1.80±0.10 <sup>a</sup>	0.58
80	25.4±1.5 <sup>bA</sup>	2.33±0.10 <sup>b</sup>	0.54	36.8±1.8 <sup>bB</sup>	2.50±0.15 <sup>b</sup>	0.60

100	29.7±1.8 <sup>bA</sup>	2.74±0.07 <sup>b</sup>	0.52	39.9±2.0 <sup>bB</sup>	2.97±0.09 <sup>b</sup>	0.59
120	32.5±2.0 <sup>bA</sup>	3.28±0.11 <sup>b</sup>	0.56	43.5±1.4 <sup>bB</sup>	3.48±0.10 <sup>b</sup>	0.56
140	36.5±2.0 <sup>bA</sup>	3.70±0.10 <sup>b</sup>	0.58	46.0±1.9 <sup>bB</sup>	3.86±0.07 <sup>b</sup>	0.58
160	31.3±1.5 <sup>cA</sup>	3.77±0.08 <sup>c</sup>	0.53	42.6±1.5 <sup>cB</sup>	3.92±0.09 <sup>c</sup>	0.53
180	28.8±1.0 <sup>cA</sup>	3.89±0.09 <sup>c</sup>	0.54	38.7±2.0 <sup>cB</sup>	4.06±0.10 <sup>c</sup>	0.59

627 Values are presented as mean ±standard deviation (n=3)

628 Values with different small superscripts in a column differ significantly at  $p<0.05$  for each test

629 Values with different capital superscripts in a row differ significantly at  $p<0.05$  for each test

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635 **Table 2** Microbial analysis of UHT treated and retort processed foxtail millet porridge during  
636 the test storage period at 25 °C

Storage period (Days)	UHT treated samples	Retort processed samples
Total plate count (log CFU/g of sample)		
0	ND	ND
30	ND	ND
60	ND	ND
90	2.11 ± 0.02 <sup>b1</sup>	2.05 ± 0.06 <sup>a1</sup>
120	3.12 ± 0.07 <sup>b1</sup>	3.07 ± 0.04 <sup>a1</sup>

150	$3.46 \pm 0.05^{b1}$	$3.23 \pm 0.06^{a1}$
180	$4.31 \pm 0.03^{b2}$	$3.98 \pm 0.08^{a2}$
Yeast and mold count (log CFU/g of sample)		
0	ND	ND
30	ND	ND
60	ND	ND
90	$2.01 \pm 0.03^{b1}$	$1.71 \pm 0.02^{a1}$
120	$2.67 \pm 0.07^{b1}$	$1.96 \pm 0.07^{a1}$
150	$3.03 \pm 0.22^{b1}$	$2.54 \pm 0.02^{a1}$
180	$3.88 \pm 0.09^{b2}$	$2.91 \pm 0.07^{a2}$

637 *ND* not detected, *CFU* colony forming unit

638 Values are presented as mean  $\pm$  standard deviation (n=3)

639 Values with different alphabetical superscripts in a column differ significantly at  $p < 0.05$  for each test

640 Values with different numerical superscripts in a row differ significantly at  $p < 0.05$  for each test

641

642 **Table 3** Check-all-that-apply (CATA) frequency table for quality attributes of UHT treated  
643 foxtail millet porridge stored at 25 °C for different storage times

Attribute	Storage time (days)									
	0	20	40	60	80	100	120	140	160	180
<b>Visual texture and appearance:</b>										
Thick*	10 <sup>a</sup>	10 <sup>a</sup>	10 <sup>a</sup>	12 <sup>a</sup>	12 <sup>a</sup>	12 <sup>a</sup>	12 <sup>a</sup>	13 <sup>a</sup>	13 <sup>a</sup>	13 <sup>a</sup>
Unevenness <sup>+</sup>	12 <sup>a</sup>	12 <sup>a</sup>	12 <sup>a</sup>	11 <sup>a</sup>	11 <sup>a</sup>	11 <sup>a</sup>	10 <sup>a</sup>	10 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>
Uniform color*	72 <sup>a</sup>	74 <sup>ab</sup>	75 <sup>ab</sup>	78 <sup>b</sup>	78 <sup>b</sup>	80 <sup>abc</sup>	83 <sup>c</sup>	84 <sup>c</sup>	84 <sup>c</sup>	86 <sup>c</sup>
Discoloration <sup>+</sup>	5 <sup>a</sup>	5 <sup>a</sup>	5 <sup>a</sup>	4 <sup>a</sup>	5 <sup>a</sup>	3 <sup>b</sup>	4 <sup>a</sup>	3 <sup>b</sup>	2 <sup>b</sup>	4 <sup>a</sup>
Curdling <sup>+</sup>	2 <sup>a</sup>	2 <sup>a</sup>	2 <sup>a</sup>	3 <sup>a</sup>	4 <sup>a</sup>	4 <sup>a</sup>	4 <sup>a</sup>	8 <sup>ab</sup>	12 <sup>b</sup>	14 <sup>b</sup>



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**In mouth texture:**

Grainy*	71 <sup>c</sup>	69 <sup>b</sup>	69 <sup>b</sup>	68 <sup>b</sup>	68 <sup>b</sup>	64 <sup>ab</sup>	61 <sup>a</sup>	61 <sup>a</sup>	61 <sup>a</sup>	60 <sup>a</sup>
Sticky <sup>+</sup>	42 <sup>a</sup>	43 <sup>a</sup>	43 <sup>a</sup>	45 <sup>ab</sup>	45 <sup>ab</sup>	49 <sup>b</sup>	50 <sup>b</sup>	51 <sup>b</sup>	54 <sup>c</sup>	56 <sup>c</sup>

**Smell:**

Caramel*	35 <sup>a</sup>	35 <sup>a</sup>	36 <sup>a</sup>	36 <sup>a</sup>	38 <sup>a</sup>	42 <sup>ab</sup>	44 <sup>abc</sup>	48 <sup>bc</sup>	51 <sup>c</sup>	52 <sup>c</sup>
Cooked <sup>+</sup>	42 <sup>a</sup>	42 <sup>a</sup>	43 <sup>a</sup>	43 <sup>a</sup>	44 <sup>a</sup>	44 <sup>a</sup>	45 <sup>ab</sup>	47 <sup>b</sup>	47 <sup>b</sup>	49 <sup>b</sup>
Sour <sup>+</sup>	7 <sup>a</sup>	8 <sup>a</sup>	8 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	11 <sup>a</sup>	11 <sup>a</sup>	12 <sup>b</sup>	13 <sup>b</sup>
Off <sup>+</sup>	6 <sup>a</sup>	6 <sup>a</sup>	6 <sup>a</sup>	7 <sup>a</sup>	7 <sup>a</sup>	8 <sup>a</sup>	8 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	11 <sup>b</sup>

**Taste:**

Caramel*	58 <sup>a</sup>	59 <sup>a</sup>	64 <sup>ab</sup>	68 <sup>b</sup>	69 <sup>b</sup>	74 <sup>bc</sup>	75 <sup>bc</sup>	79 <sup>c</sup>	82 <sup>c</sup>	83 <sup>c</sup>
Cooked <sup>+</sup>	63 <sup>a</sup>	65 <sup>b</sup>	66 <sup>b</sup>	68 <sup>b</sup>	69 <sup>b</sup>	69 <sup>b</sup>	75 <sup>bc</sup>	76 <sup>bc</sup>	78 <sup>c</sup>	79 <sup>c</sup>
Sour <sup>+</sup>	8 <sup>a</sup>	8 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	10 <sup>a</sup>	11 <sup>a</sup>	11 <sup>a</sup>	12 <sup>a</sup>
Off <sup>+</sup>	6 <sup>a</sup>	6 <sup>a</sup>	7 <sup>a</sup>	7 <sup>a</sup>	8 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	10 <sup>a</sup>	11 <sup>b</sup>	11 <sup>b</sup>

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644 Values with different superscripts in rows represent significant differences ( $p < 0.05$ ,  $n=100$ )

645 \*Positive sensory attributes

646 <sup>+</sup>Negative sensory attributes

647

648

649 **Table 4** Check-all-that-apply (CATA) frequency table for quality attributes of retort  
650 processed foxtail millet porridge stored at 25 °C for different storage times

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Attribute	Storage time (days)									
	0	20	40	60	80	100	120	140	160	180
<b>Visual texture and appearance:</b>										
Thick*	42 <sup>a</sup>	43 <sup>a</sup>	43 <sup>a</sup>	43 <sup>a</sup>	45 <sup>a</sup>	46 <sup>ab</sup>	48 <sup>ab</sup>	49 <sup>b</sup>	49 <sup>b</sup>	52 <sup>b</sup>
Unevenness <sup>+</sup>	21 <sup>a</sup>	23 <sup>a</sup>	23 <sup>a</sup>	26 <sup>b</sup>	27 <sup>b</sup>	28 <sup>bc</sup>	28 <sup>bc</sup>	32 <sup>c</sup>	33 <sup>c</sup>	34 <sup>c</sup>
Uniform color*	78 <sup>a</sup>	79 <sup>a</sup>	79 <sup>a</sup>	80 <sup>a</sup>	84 <sup>ab</sup>	85 <sup>b</sup>	86 <sup>b</sup>	89 <sup>bc</sup>	94 <sup>c</sup>	95 <sup>c</sup>
Discoloration <sup>+</sup>	11 <sup>a</sup>	12 <sup>a</sup>	12 <sup>a</sup>	13 <sup>a</sup>	14 <sup>a</sup>	15 <sup>a</sup>	16 <sup>a</sup>	16 <sup>a</sup>	17 <sup>b</sup>	19 <sup>b</sup>

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Curdling <sup>+</sup>	4 <sup>a</sup>	5 <sup>a</sup>	5 <sup>a</sup>	5 <sup>a</sup>	6 <sup>a</sup>	6 <sup>a</sup>	7 <sup>a</sup>	8 <sup>a</sup>	8 <sup>a</sup>	9 <sup>a</sup>
<b>In mouth texture:</b>										
Grainy <sup>*</sup>	83 <sup>c</sup>	82 <sup>c</sup>	78 <sup>bc</sup>	75 <sup>b</sup>	74 <sup>b</sup>	73 <sup>b</sup>	72 <sup>b</sup>	69 <sup>a</sup>	69 <sup>a</sup>	68 <sup>a</sup>
Sticky <sup>+</sup>	54 <sup>a</sup>	56 <sup>a</sup>	58 <sup>a</sup>	62 <sup>b</sup>	63 <sup>b</sup>	65 <sup>bc</sup>	67 <sup>c</sup>	68 <sup>c</sup>	68 <sup>c</sup>	70 <sup>c</sup>
<b>Smell:</b>										
Caramel <sup>*</sup>	68 <sup>a</sup>	68 <sup>a</sup>	69 <sup>a</sup>	74 <sup>a</sup>	78 <sup>ab</sup>	79 <sup>b</sup>	79 <sup>b</sup>	83 <sup>bc</sup>	84 <sup>bc</sup>	88 <sup>c</sup>
Cooked <sup>+</sup>	81 <sup>a</sup>	84 <sup>ab</sup>	85 <sup>b</sup>	85 <sup>b</sup>	89 <sup>bc</sup>	89 <sup>bc</sup>	92 <sup>abc</sup>	93 <sup>c</sup>	93 <sup>c</sup>	94 <sup>c</sup>
Sour <sup>+</sup>	10 <sup>a</sup>	11 <sup>a</sup>	11 <sup>a</sup>	12 <sup>a</sup>	12 <sup>a</sup>	13 <sup>a</sup>	15 <sup>b</sup>	16 <sup>b</sup>	17 <sup>b</sup>	17 <sup>b</sup>
Off <sup>+</sup>	8 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	10 <sup>a</sup>	11 <sup>a</sup>	11 <sup>a</sup>	11 <sup>a</sup>	12 <sup>a</sup>
<b>Taste:</b>										
Caramel <sup>*</sup>	81 <sup>a</sup>	82 <sup>a</sup>	82 <sup>a</sup>	86 <sup>ab</sup>	88 <sup>b</sup>	89 <sup>b</sup>	91 <sup>b</sup>	91 <sup>b</sup>	92 <sup>b</sup>	93 <sup>b</sup>
Cooked <sup>+</sup>	80 <sup>a</sup>	80 <sup>a</sup>	81 <sup>a</sup>	82 <sup>a</sup>	83 <sup>a</sup>	83 <sup>a</sup>	85 <sup>b</sup>	87 <sup>b</sup>	87 <sup>b</sup>	88 <sup>b</sup>
Sour <sup>+</sup>	6 <sup>a</sup>	6 <sup>a</sup>	7 <sup>a</sup>	7 <sup>a</sup>	7 <sup>a</sup>	9 <sup>a</sup>	9 <sup>a</sup>	10 <sup>a</sup>	11 <sup>a</sup>	11 <sup>a</sup>
Off <sup>+</sup>	5 <sup>a</sup>	6 <sup>a</sup>	7 <sup>a</sup>	7 <sup>a</sup>	8 <sup>a</sup>	8 <sup>a</sup>	9 <sup>a</sup>	10 <sup>a</sup>	10 <sup>a</sup>	11 <sup>a</sup>

651 Values with different superscripts in rows represent significant differences ( $p < 0.05$ ,  $n=100$ )

652 \*Positive sensory attributes

653 <sup>+</sup>Negative sensory attributes

654

655 **Table 5** Comparison of log-likelihood values for different distribution curves

Distribution model	Log-likelihood values
Weibull	128.3
Logistic	131.4
Gaussian	134.6
Log-logistic	129.2
Exponential	138.9

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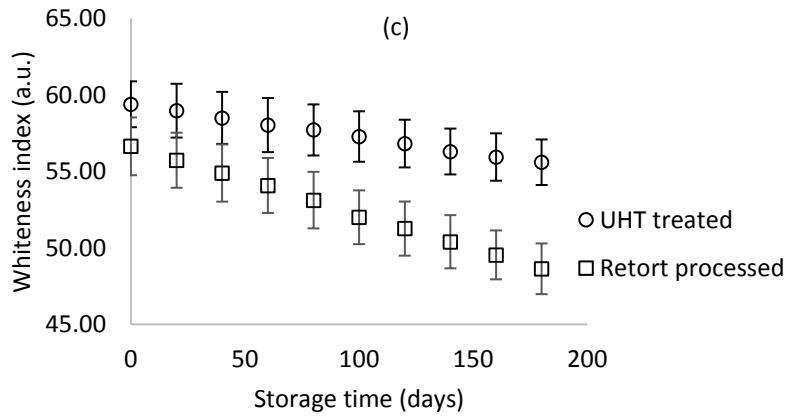
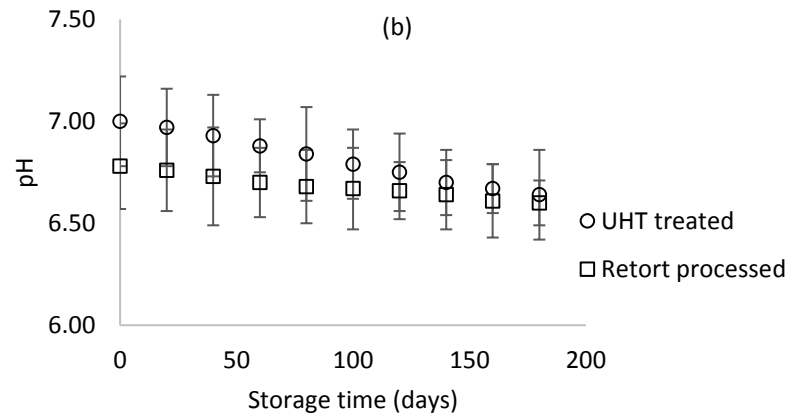
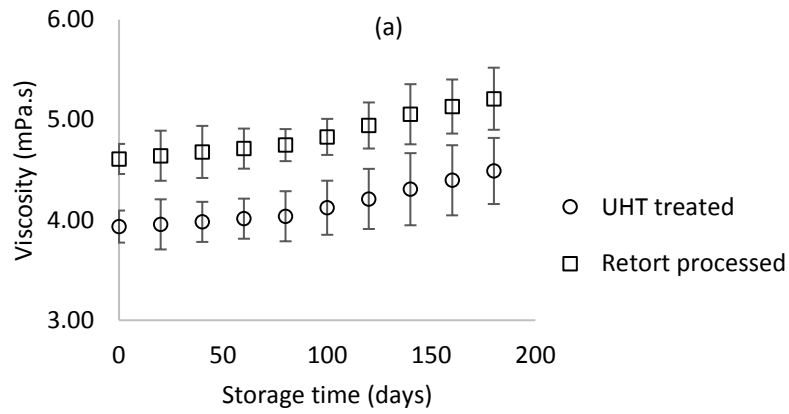
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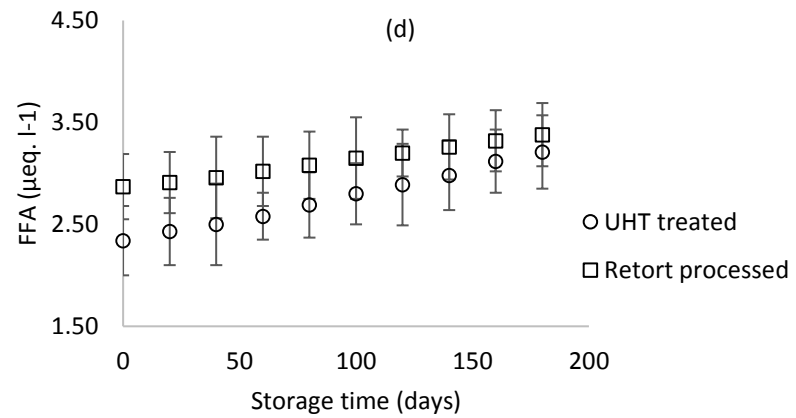
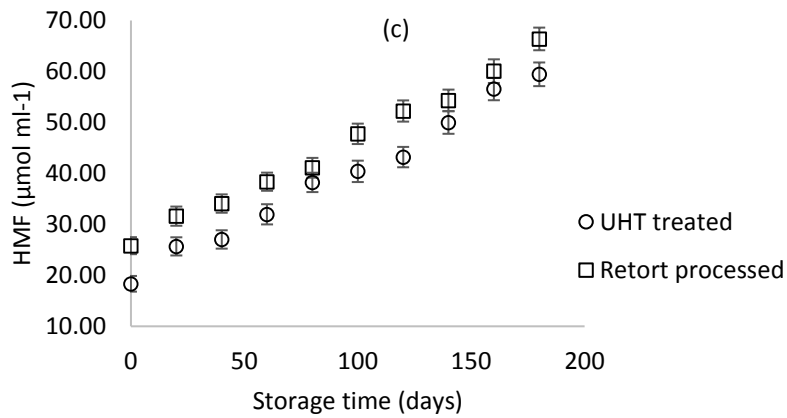
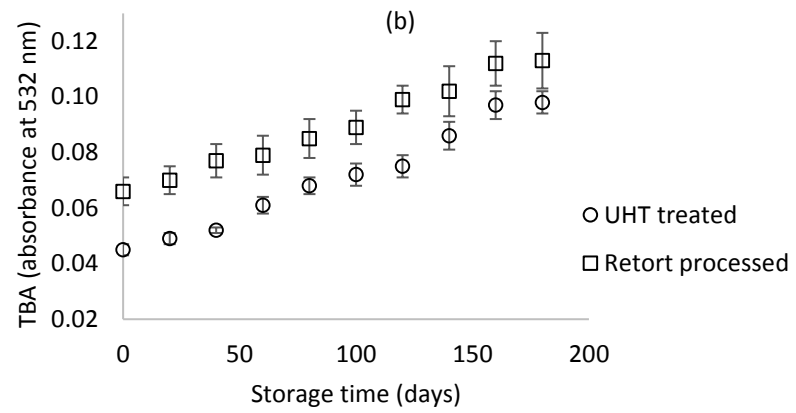
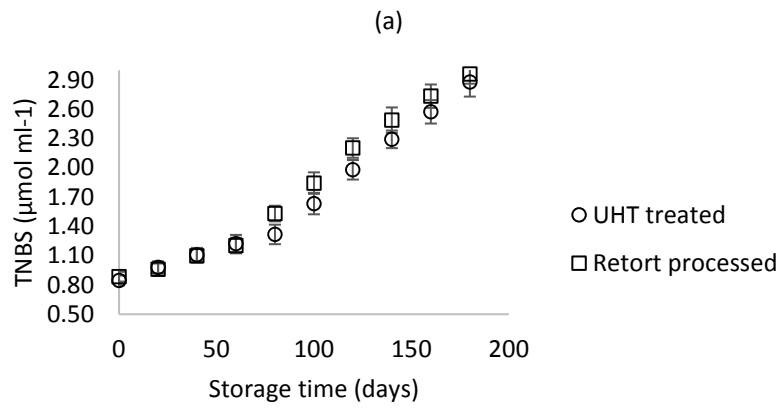


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673 **Figure 1** Changes in (a) viscosity, (b) pH, and (c) whiteness index during storage of packaged foxtail millet porridge at 25 °C.

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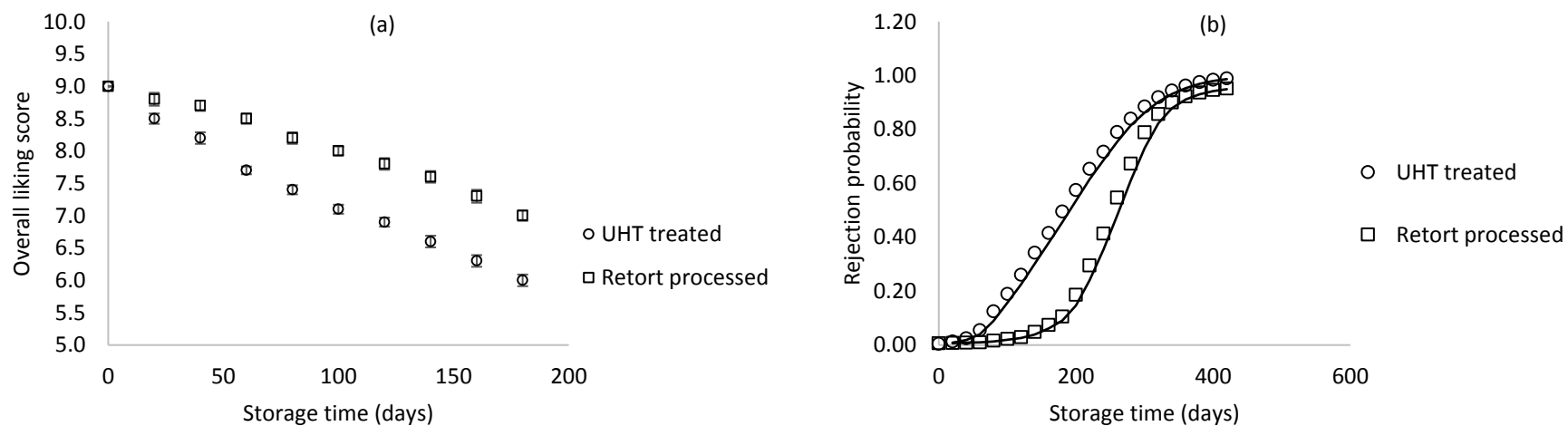
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677 **Figure 2** Changes in (a) trinitrobenzene sulfonic acid (TNBS), (b) thiobarbituric acid (TBA), (c) hydroxymethylfurfural (HMF), and (d)  
 678 fatty acid (FFA) value during storage of packaged foxtail millet porridge at 25 °C.

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680



681

682 **Figure 3** (a) Change in overall liking score as rated on a 9-point hedonic scale (b) consumer rejection probability for packaged foxtail

683 millet porridge stored at 25 °C

684