Development and quality evaluation of retort processed RTE functional gluten free foxtail millet halwa

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Summary

The present study focuses on the replacement of wheat and the development of ethnic RTE Indian products. Gluten, a protein complex present in wheat, causes celiac disease and gluten sensitivity in people. Foxtail Millet is one such cereal, which can be substituted for wheat due to its availability and nutritional importance. *Halwa* is a delicious sweet dessert rich in fat and carbohydrates, which is prepared mainly in North India. Through retort processing, the shelf life of *halwa* can be increased to make these products available for an increased period. The RTE foxtail millet *halwa* was prepared and retorted to the total lethality value of 5.26 minutes. Retorting has significantly reduced the total microbial population and much less physico-chemical changes were recorded after processing, when compared to the control. The retorted products were stored under refrigerated and ambient conditions and the changes in physico-chemical properties were evaluated. During the storage period, the shelf life study revealed that there were much less significant changes in the physico-chemical properties under both storage conditions. Though, there was a comparatively equal amount of changes occurring in both the refrigerated storage and ambient storage conditions, the appearance and texture of the products stored in ambient storage conditions rather than in refrigerated conditions were found to be good. Hence, ambient storage conditions can be suggested for storage of these products after retorting.

Keywords: gluten-free, foxtail millet, ready-to-eat (RTE), halwa, retort processing

Introduction

Halwa is a dessert (sweet Indian dish) made from various kinds of fruits, vegetables, grains, and lentils, boiled with milk, almonds, sugar, butter, and cardamom (Verma et al., 2014). Even though *halwa* may be flour based or nut based, the common form of *halwa* is mainly prepared using wheat semolina (Sooji). Wheat semolina contains gluten, one of the many proteins found in wheat. It comprises of two protein groups, namely gliadin and glutenin. Gluten gives wheat its strength, malleability, and the elasticity that allows it to rise. The gliadin portion, which is a type of prolamin and the most studied protein fraction, has been recognized since the 1960s as the cause of the intestinal damage seen in celiac disease (Helms and Steve, 2005). Hence, an alternative for wheat is needed. Since millets are devoid of gluten proteins, they can be used as a substitute for wheat products, which are rich in antioxidants and essential nutrients such as B vitamins and minerals, as well as nutraceuticals (Jaybhaye et al., 2014).

Foxtail millet shows major potential because of its high dietary fibre content and other essential nutrients, when compared to other millets. This millet has been proved to be suitable for people suffering from metabolic disorders (Ballolli et al., 2014). It contains nearly 15% protein, contains moderate amounts of fibre, B-complex vitamins including niacin, thiamine, and riboflavin, the essential amino acid methionine, lecithin, and some vitamin E. It is particularly high in the minerals iron, magnesium, phosphorous, and potassium (Mohamed et al., 2012). Though the product is developed, it has to be stored for a long period for easy availability.

Thermal processing is one of the most effective methods of preservation through which the shelf life of products is extended. Retort pouch processing is a thermal processing method which is widely used for RTE products. Flexible retortable pouches represent a unique alternative packaging method for sterile shelf-stable products. A typical four ply pouch would have an outer layer of polyethylene terephthalate (PET) for heat resistance, aluminium foil as an oxygen/light barrier, biaxial orientated nylon for resilience, and an inner-cast poly-propylene for pack sealing. Each layer has an adhesive in between it and the next layer. The most important feature of these packages is to produce a contamination free seal, which will maintain the shelf life of the product. Therefore, filling and sealing are slow processes if an effective seal is to be achieved. Retortable pouches have several advantages over traditional cans. Slender pouches are more easily disposed of than comparatively bulky cans. Shipping them is easier. In addition, the “fresher” retortable pouch product

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obviously requires significantly less heat to achieve commercial sterility. Furthermore, cooking time is about half that required for traditional cans, resulting in tremendous energy savings (Holdsworth and Simpson, 2007). Due to the requirement for RTE products, the present work was taken with the following objectives: To develop ethnic RTE *halwa* by substituting wheat with foxtail millet, to extend the shelf life of the RTE foxtail millet *halwa* developed by retort processing, and to evaluate the product's physico-chemical properties during its storage period.

Materials and methods

Sample preparation

The foxtail millet for the preparation of *halwa* was procured from the local markets of Mysore. The foxtail millet was cleaned with chlorinated water for 5 minutes to remove the external debris and dust. Then it was shade dried till the moisture adhering over the surface was removed. The cleaned millets were roasted in refined sunflower oil and after roasting they were ground to semolina consistency. The *halwa* was then prepared with ghee, oil, water, cashew, and cardamom (seasoning). The samples were hot filled (200 g) in pre-fabricated multilayer laminated retortable pouches having a capacity of 300 g, consisting of 12 µm Polyester/ 12 µm Aluminium foil/ 10 µm Nylon/ 75 µm Cast- Polypropylene (PET/ Aluminium foil/ Nylon/ C.PP), of dimensions 15 cm × 20 cm, under sterile conditions. The air present in the head space was manually squeezed out and sealed using a High Pressure Impulse Sealer (Model: HP Impulse Sealer, M/S Sunray Industries Mysore, India).

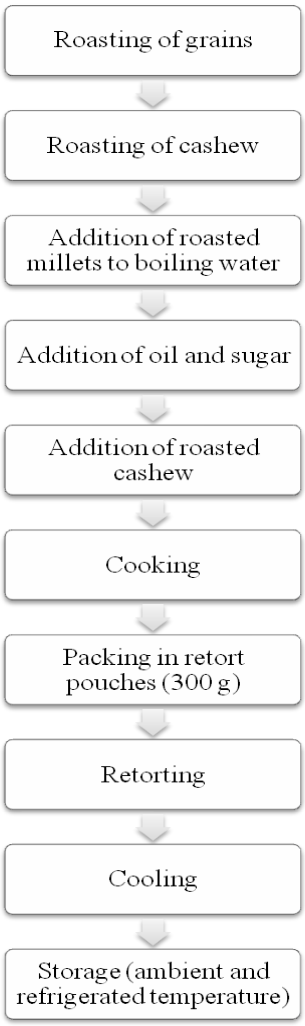

Fig. 1. Preparation and processing of foxtail millet halwa

Retort processing

The pouches were enclosed in retort moulds and the process was carried out in a steam - air retort (M/s. Alpha Steritech, Bangalore, India). The retort is equipped with a facility for compressed air, used for raising the pressure, and with a high pressure water circulating pump used to provide pressurized water for the rapid cooling of hot pouches. The temperature was monitored at regular intervals of 1 minute using iron - constantan thermocouples, fixed at the geometric centre of the pouches, coupled with a data logger (Model: E. Val flex, M/s. Ellab, Denmark). The F_0value was calculated from the temperature and time history. The pouches were initially heated till the inside temperature reached 100 ºC. Subsequently, the pressure of the steam was raised in stages; from 5 psi to 15 psi gauge pressure progressively with the increase in temperature. The processing was carried out to achieve a value of 4.5, with the maximum temperature of 120 ºC, as stated in Kumar et al. (2013) and Lakshmana et al. (2013). After attaining the required F_0 value, the product temperature was brought down to 45 ºC by pressurized cooling (compressed air and water) in 4-5 minutes. The cooled pouches were wiped dry and examined for any visual defects.

Storage

The foxtail millet *halwa* and foxtail millet upma pouches were packed in 2 separate corrugated paperboard boxes and stored in two different storage conditions viz. ambient temperature (27-30 ºC) and refrigerated temperature (5 ºC). The samples were analyzed for their physical and biochemical properties at an interval of 90 days.

Proximate analysis

The product was analyzed for its water activity using a water activity meter (Model: Labmaster a_w, Novasina, Switzerland); for moisture content, free fatty acids, peroxide value, total protein (Micro Kjeldahl method), and total ash by using the methods suggested by Ranganna (2000), and for total carbohydrates and reducing sugars by using the methods suggested by Sadasivam and Manickam (2010) at regular intervals (90 days). The samples were also tested for colour values using a Hunter Lab Colorimeter (Model: Colour Flex EZ, Hunter Lab, USA).

Microbial analysis

The foxtail millet *halwa* samples were tested for Total Plate Count (TPC), Yeasts and Moulds count, and Coliforms (before and after processing); and for Anaerobic Count (after processing). The pouches were incubated at 37 and 55 °C for seven days. SPC was determined using dextrose tryptone agar (DTA), after incubation for 48 h at 30 ºC. Yeast and moulds were estimated with the help of acidified potato dextrose agar (PDA), after incubation at 30 °C for four to five days. Spore formers were determined after killing the vegetative cells by keeping the sample in a boiling water bath for 10 to 20 min, and subsequently incubated at 37 and 55 °C for 48 h after incubation (Harrigan and McCance, 1976).

Statistical analysis

All the experiments were performed in triplicate and the analysis of variance (ANOVA) was carried out for the experimental values in order to find out the significant difference (at 5% significant level), using statistical software (CoStat Version 6.204).

Results and discussion

Proximate composition of foxtail millet halwa

The proximate composition of Foxtail Millet *Halwa* before and after retort processing is presented in Table 1. The moisture content of the sample has decreased after retort processing, whereas the protein content, crude fibre content, and the reducing sugars of the samples increased after retorting. But the fat content, total carbohydrates, and ash content of the samples before and after processing have remained constant. The FFA content of the retorted sample was comparatively higher than the unprocessed sample, which may be due to the hydrolysis of fats during retort processing at high temperature. The Peroxide value of the retorted sample has also increased, indicating that the peroxides have formed in the unsaturated linkages of the fat due to high temperature processing. Verma et al. (2014) also prepared foxtail millet halwa which had a nutrient composition of 1.89% protein, 9.60% fat, 0.78% fibre, 30.70% total carbohydrates, and total energy value of 216 kcal/100 g of halwa.

Table 1. Proximate composition of foxtail millet *halwa* before and after retort processing

Composition	Before Processing	After Processing
Moisture Content (%)	47.22 ± 0.22	46.30 ± 0.22
Protein (%)	2.77 ± 0.11	2.82 ± 0.3
Ash (%)	0.24 ± 0.007	0.24 ± 0.023
Crude Fibre (%)	2.55 ± 0.09	2.76 ± 0.13
Fat (%)	2.69 ± 0.37	2.75± 0.43
Total Carbohydrates (%)	43.93 ± 0.2	43.96 ± 0.08
Reducing Sugars (%)	1.23 ± 0.05	3.00 ± 0.11
Non-Reducing Sugars (%)	42.70 ± 0.09	40.96 ± 0.12
Energy, kcal/100 g	216.2	217.1

All values are in mean ± SD of data from 3 individual experiments

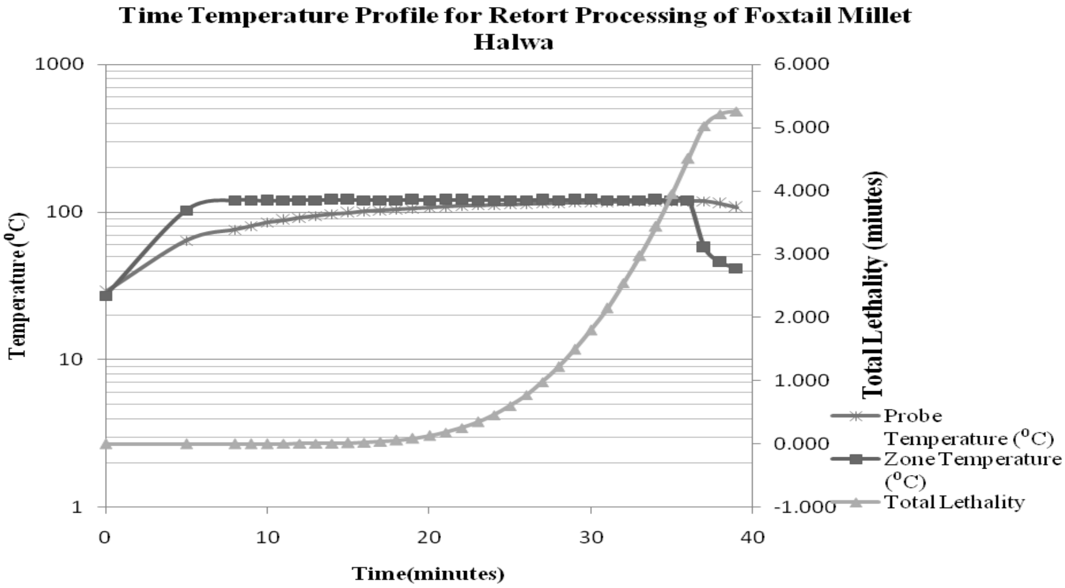

Fig. 2. Time temperature profile for retort processing of foxtail millet halwa

Retort processing of foxtail millet halwa

Foxtail millet *halwa* was packed in retort pouches under aseptic conditions. The product was retorted in a steam air retort with a total lethality value (F_0) of 5.26 minutes in order to attain both commercial sterility and reduced spoilage. The time, temperature, and the lethality profile of retort processing of foxtail millet *halwa* are presented in Fig. 2.

Microbial analysis of foxtail millet halwa

The samples were analysed for microbes before and after retort processing. The initial microbial content of the samples before and after retorting were given in Table 2. From Table 2 we can see that the TPC of the sample has reduced from 2.0×10^2 to nil after retort processing and the spores and anaerobes counts have also been found to be nil after the processing, indicating that the product is safe to consume and has reduced spoilage. Similar results were obtained by Kumar et al. (2013) for retort processed and gamma irradiated RTE chicken pulav, Kumar et al. (2015) for retort processed RTE egg curry and egg burji, Sreelakshmi et al. (2013) for retort pouch processed RTS crab sandwich spread, and Lakshmana et al. (2013) for retort processed RTE tender jack fruit curry.

Storage ctudies of foxtail millet halwa

The retort processed foxtail millet *halwa* was packed and stored in two different storage environments viz. ambient temperature and refrigerated temperature. The stored retort processed foxtail millet *halwa* was studied for its proximate composition and storage changes at an interval of 90 days.

Moisture content

Moisture content changes in the retorted samples during the storage period are presented in Table 3. There is a significant increase in the moisture content of the retort processed foxtail millet *halwa* stored at both storage conditions ($p < 0.05$). No significant changes between the two storage conditions were observed ($p > 0.05$). Lakshmana et al. (2013) have also reported that the moisture content increase was also found in retort pouch processed tender jackfruit curry during its storage period of 12 months.

Water activity

The changes in water activity of the retorted samples during the storage period are given in Table 3. Water activity of the retort processed foxtail millet *halwa* stored at both storage conditions increased significantly during the storage period of 360 days ($p < 0.05$). Even though the water activity of the samples is greater than 0.9, the spoilage of the product may not occur, since the product is retorted at higher temperature leading to microbial death and damage in cellular structure. No significant changes were observed between the storage conditions ($p > 0.05$).

Table 2. Microbial content of foxtail millet halwa before and after retort processing

Sample	TPC (CFU/g)	Spores (CFU/g)	Anaerobes (CFU/g)
Before Processing	2.0 X10^2	Absent	Absent
After Processing (at 37 °C)	Absent	Absent	Absent
After Processing (at 55 °C)	Absent	Absent	Absent

Table 3. Changes in moisture content of retort processed foxtail millet halwa

Storage Period (Days)	Moisture Content, wb (%)		Water Activity, a_w	
	Ambient temperature	5 ºC	Ambient temperature	5 ºC
0	46.30 ± 0.22 ^{eA}	46.30 ± 0.22 ^{eA}	0.946 ± 0.001 ^{eA}	0.946 ± 0.001 ^{eA}
90	47.20 ± 0.60 ^{dA}	47.01 ± 0.18 ^{dA}	0.946 ± 0.004 ^{dA}	0.946 ± 0.002 ^{dA}
180	48.23 ± 0.33 ^{cA}	48.15 ± 0.07 ^{cA}	0.947 ± 0.003 ^{cA}	0.947 ± 0.002 ^{cA}
270	48.47 ± 0.23 ^{bA}	48.26 ± 0.15 ^{bA}	0.949 ± 0.002 ^{bA}	0.948 ± 0.002 ^{bA}
360	48.52 ± 0.19 ^{aA}	48.43 ± 0.14 ^{aA}	0.950 ± 0.002^{aA}	0.949 ± 0.003^{aA}

All values are in mean ± SD of data from 3 individual experiments. Different small letter superscripts show the significant difference among rows at $p \leq 0.05$. Different capital letter superscript shows the significant difference among columns at $p \leq 0.05$

Table 4. Changes in FFA content and peroxide values of retort processed foxtail millet halwa

Storage Period (Days)	Free Fatty Acids (% of oleic acid)		Peroxide value (meq of peroxide/kg)	
	Ambient temperature	5 ºC	Ambient temperature	5 ºC
0	1.85 ± 0.14^{dA}	1.85 ± 0.14^{bA}	10.46 ± 0.79^{bA}	10.46 ± 0.79^{bA}
90	2.03 ± 0.10^{cA}	2.12 ± 0.06^{aA}	13.35 ± 1.15^{aA}	11.76 ± 2.63^{aB}
180	2.20 ± 0.05^{bA}	2.23 ± 0.07^{aA}	6.40 ± 0.36^{cB}	7.96 ± 0.54^{cA}
270	2.20 ± 0.09^{bB}	2.23 ± 0.05^{aA}	3.98 ± 0.28^{dB}	5.11 ± 0.66^{dA}
360	2.35 ± 0.08^{aA}	2.28 ± 0.04^{aA}	2.95 ± 0.28^{eB}	3.34 ± 0.66^{eA}

All values are in mean ± SD of data from 3 individual experiments. Different small letter superscript shows the significant difference among rows at $p \leq 0.05$. Different capital letter superscript shows the significant difference among columns at $p \leq 0.05$

Free fatty acids and peroxide value

Acid value is the number of milligrams of KOH required to neutralise the free fatty acids present in one gram of oil or fat. The peroxide value of an oil or fat is the amount of peroxides present and expressed as milli equivalents of peroxide per 1000 g of sample. The FFA value and peroxide value indicate the rancidity of the oils and fats present in the food samples. Table 4 shows that the FFA content of the retort processed foxtail millet *halwa* stored at both conditions increased significantly ($p < 0.05$), whereas the peroxide value increased and decreased significantly ($p < 0.05$) in both the storage conditions with the storage period. But no significant changes were observed between the two conditions ($p > 0.05$).

Total carbohydrates and reducing sugars

The total carbohydrates include both reducing sugars and non-reducing sugars present in the sample. The sugars with the reducing property are called reducing sugars. Some of the reducing sugars are glucose, galactose, lactose, and maltose. The total carbohydrates (Table 5) decreased significantly ($p < 0.05$), whereas the reducing sugars increased significantly ($p < 0.05$) during the storage period in both storage conditions. But no significant changes were observed between both conditions for total carbohydrates and reducing sugars ($p > 0.05$). The increase in the reducing sugars might be due to the hydrolysis of complex sugars during the storage period.

Colour values

The "L" value depicts the lightness or darkness of the samples, the "a" value depicts the redness or greenness of the samples, the "b" value depicts the blueness or yellowness of the sample, and the dE* value depicts the total colour change of the sample, which was calculated using the formula,

$$dE^* = \sqrt{\left(a^*_{ref} - a^*_{sample}\right)^2 + \left(b^*_{ref} - b^*_{sample}\right)^2 + \left(L^*_{ref} - L^*_{sample}\right)^2} \qquad (1)$$

From Table 6 we can imply there were no significant changes ($p > 0.05$) in the L*, a*, b*, and dE* values during the storage period in both of the storage conditions (ambient and 5 °C temperature). Similarly, no significant changes occurred between the two storage conditions ($p > 0.05$).

Non enzymatic browning

In halwa, the non enzymatic browning is mainly due to the Maillard reaction and caramelisation. The non enzymatic browning changes for the foxtail millet *halwa* are discussed in Table 7. The non enzymatic browning due to the Maillard reaction has decreased significantly ($p < 0.05$) during the storage period in both conditions. There were insignificant changes between the two storage conditions ($p > 0.05$). Since the non enzymatic browning has decreased over the storage period, it indicates that the browning is mainly due to the Maillard reaction, which is reversible in its initial stages, as stated by Rufián-Henares et al. (2009).

Table 5. Changes in total carbohydrates and reducing sugars of retort processed foxtail millet halwa

Storage Period (Days)	Total Carbohydrates, db (%)		Reducing Sugars, db (%)	
	Ambient temperature	5 ºC	Ambient temperature	5 ºC
0	43.14 ± 0.08^{aA}	43.14 ± 0.08^{aA}	3.01 ± 0.11^{eA}	3.01 ± 0.11^{eA}
90	42.17 ± 0.03^{bA}	35.04 ± 0.07^{bB}	32.90 ± 0.05^{dA}	14.70 ± 0.23^{dB}
180	35.67 ± 0.02^{cA}	34.91 ± 0.01^{bB}	35.30 ± 0.12^{cA}	24.72 ± 0.14^{cB}
270	33.55 ± 0.06^{dA}	32.21 ± 0.03^{cB}	41.20 ± 0.13^{bA}	36.48 ± 0.10^{bB}
360	30.99 ± 0.15^{eA}	30.34 ± 0.11^{dB}	42.99 ± 0.02^{aA}	37.12 ± 0.1^{aB}

All values are in mean ± SD of data from 3 individual experiments. Different small letter superscripts show the significant difference among rows at $p \leq 0.05$. Different capital letter superscript shows the significant difference among columns at $p \leq 0.05$

Table 6. Changes in colour value of retort processed foxtail millet halwa

Storage Period (Days)	L*		a*		b*		dE*	
	Ambient temperature	5 ºC	Ambient temperature	5 ºC	Ambient temperature	5 ºC	Ambient temperature	5 ºC
0	53.97 ± 0.88^{aA}	53.97 ± 0.88^{aA}	2.78 ± 1.56^{aA}	2.78 ± 1.56^{aA}	20.91 ± 1.37^{aA}	20.91 ± 1.37^{aA}	1.7 ± 0.2^{aA}	1.7 ± 0.2^{aA}
90	56.09± 0.06^{aA}	54.57± 0.13^{aA}	2.72± 0.05^{aA}	3.26± 0.01^{aA}	20.94± 0.04^{aA}	17.99 ± 0.13^{aA}	2.49± 0.09^{aA}	1.18± 0.08^{aA}
180	67.09 ±0.05^{aA}	55.38± 0.12^{aA}	2.85 ± 0.03^{aA}	2.44 ± 0.03^{aA}	20.52 ± 0.03^{aA}	18.04 ± 0.03^{aA}	2.07 ± 0.05^{aA}	1.91± 0.02^{aA}
270	55.05± 0.12^{aA}	56.19± 0.06^{aA}	2.95± 0.02^{aA}	2.44± 0.02^{aA}	19.76± 0.04^{aA}	19.62 ± 0.12^{aA}	3.13± 0.03^{aA}	2.03 ± 0.02^{aA}
360	53.95 ± 0.27^{aA}	56.89 ± 0.1^{aA}	3.09 ± 0.03^{aA}	2.38 ± 0.19^{aA}	18.98 ± 0.22^{aA}	20.05 ± 0.10^{aA}	2.51 ± 0.16^{aA}	3.71 ± 0.03^{aA}

All values are in mean ± SD of data from 3 individual experiments. Different small letter superscript shows the significant difference among rows at $p \leq 0.05$. Different capital letter superscript shows the significant difference among columns at $p \leq 0.05$

Table 7. Changes in Non Enzymatic Browning (NEB) of retort processed foxtail millet halwa

Storage Period (Days)	Non Enzymatic Browning (%)	
	Ambient temperature	5 °C
0	96.40 ± 0.25^{aA}	96.40 ± 0.25^{aA}
90	39.64 ± 0.12^{bA}	37.84 ± 0.33^{bA}
180	30.63 ± 0.43^{cA}	29.73 ± 0.49^{cA}
270	9.25 ± 0.04^{dA}	8.21 ± 0.19^{dA}
360	2.70 ± 0.07^{eA}	3.67 ± 0.14^{eA}

All values are in mean ± SD of data from 3 individual experiments. Different small letter superscript shows the significant difference among rows at $p \leq 0.05$. Different capital letter superscript shows the significant difference among columns at $p \leq 0.05$

Conclusions

Gluten, a protein complex present in wheat, causes celiac disease and gluten sensitivity in people. Hence, gluten free diets are practised nowadays. Foxtail Millet is one of the cereals which can be substituted for wheat, due to its higher availability and nutritional importance than any other cereals. Among various wheat products, *halwa* is the widely consumed dessert, mainly in South India. Retort pouch processing technology was used to increase the shelf life of foxtail millet *halwa*. The foxtail millet *halwa* was retorted with a total lethality (F_0) value of 5.26 minutes, respectively and it was stored in both ambient temperature and refrigerated temperature. TPC (CFU/g), Spores (CFU/g), and Anaerobes (CFU/g) were observed to be nil in the retorted pouches. During the period of study (360 days), the quality attributes of the processed RTE foxtail millet halwa was found to be retained with negligible changes, proving to be shelf stable at ambient conditions.

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