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Storage study of Ready-To-Eat raw banana flour fortified extruded snack

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Abstract
The aim of this study was to investigate the effect of storage period on the quality attributes of Ready-To-Eat raw banana flour fortified extruded snack. The fortified extruded snacks were packed in aluminium laminated polyethylene and stored for a period of 3 months under ambient condition and were evaluated at an interval of 15 days. The packaging material as well as storage period had significant effect on moisture content (%), water activity (a_w), vitamin C (mg/100g), non-enzymatic browning reaction (OD value), microbial population (CFU g^{-1}) and organoleptic evaluation. The results indicated that aluminium laminated polyethylene pouches can be utilized to store the raw banana flour fortified extruded snacks for three months under ambient storage conditions with minimal changes in the quality of snacks.

Keywords: Fortified extruded snack, aluminium laminated polyethylene and storage period

Introduction
The pandemic and increased awareness of sustainability, zero waste and clean eating habits have played a significant role in paradigm shift in food preferences of the consumers. More consumers are educating themselves about what they consume, they are concerned not only about what they eat and drink but also about where the food products and ingredients come from and how the packaging is made of to ensure that the foodstuffs and manufacturing process are good for their body and the planet.

Hot extrusion generally consists of thermo-mechanical transformation of raw materials in high temperature and short time (HTST) conditions under pressure. Extrusion is often characterized by continuous cooking, mixing and forming processing and produces direct expanded materials of high quality (Choton *et al.*, 2020) [1]. Extrusion technology is increasingly being employed in the production of snack foods, and it has been investigated in connection with improving the dietary profile of snacks (Potter *et al.*, 2013) [2].

Most extruded products are primarily composed of corn grits, which provide all of the characteristics required for the production of highly acceptable extruded snack foods, but their nutritional value is substantially short of satisfying the requirements of health-conscious consumers. As a result, there is opportunity to develop fortified extruded snacks by incorporating fruits and vegetables to diversify the nutrient content of the extrudates. Altan *et al.* (2008) [3] reported that addition of tomato will enhance the total antioxidant activity and total phenolic content of the extruded product.

Consumers are constantly concerned about the shelf life and quality degradation of food products during storage. In addition to the primary requirement that food product must remain safe, these expectations also pertain to minimizing unwanted changes to the food's sensory characteristics. During storage, expanded food products, especially extruded food, are susceptible to changes due to a variety of chemical, microbiological, and biochemical reactions occurring over time within the food matrix (Yadav *et al.*, 2018) [4]. Therefore, maintaining the desired quality of food products depends on proper packaging and optimum storage conditions. Accordingly, the current investigation aims to assess the storage stability of fortified RTE extruded snacks stored in aluminium laminated polyethylene (ALPE) pouches under ambient condition.

Material and Methods
Materials
The investigation was carried out in the Department of Post Harvest Technology, College of Horticulture, Bengaluru, Karnataka, during the year 2021-22. Raw banana was obtained from Sai Farmiculture Pvt. Ltd., Bengaluru. Kokum rind was procured from Kadamba market, Sirsi. Moringa leaves were procured from Bioversity orchard, College of Horticulture, Bengaluru, whereas, foxtail millet grits, maize grits, tomato, onion, peri peri masala, salt, oil and garlic powder were procured from local market, Vidyaranyapura. ALPE pouches were brought from K R market, Bengaluru.

Experimental design
Completely randomized design (CRD) was used to analyze the data obtained from the experiment. Web Agri. Stat. Package 2 created by the ICAR research complex in Goa was used for the analysis. A total of 3 treatments were conducted with 5 replicates.

Preparation of fortified extruded snacks
The twin screw extruder laboratory model (company: K K Life sciences, Tamil Nadu) fixed with 3 mm diameter die was used to carryout extrusion. The temperatures of the barrels and screw speed were standardized based on preliminary trails. The extrudates were prepared using maize grits, banana flour, foxtail millet grits, dehydrated tomato powder (DTP), dehydrated moringa leaf powder (DMLP), dehydrated kokum powder (DKP), onion powder (OP), garlic powder (GP), chilli powder (CP), salt and oil. The extruded product was held in a tray dehydrator set to 70 °C for about 45 minutes to achieve crispness and equalise moisture content.

Storage studies
Fortified extruded snack was packed in aluminium laminated polyethylene pouches under ambient storage condition. The samples were analysed at 15 days intervals and subjected to various physio-chemical and sensory tests to determine the quality changes in the product during storage.

Methodology used for estimating various parameters
Moisture content (%)
The moisture content of known quantity of sample was determined by using infrared moisture analyzer (Sartorius MA 35) and expressed in per cent (Thejas *et al.*, 2021) [5].

Water activity (a_w)
The water activity of the extruded product was measured by using water activity meter (Rotronic HygroLab) (Dar *et al.*, 2016) [6].

Vitamin C (mg/100g)
The vitamin C of sample's content was determined titrimetrically using 2,6-dichlorophenol indophenol dye. The sample (1 g) was diluted with 4 per cent oxalic acid. Then 10 ml of aliquot taken from the sample was titrated against 2,6-dichlorophenol indophenol. The results are expressed as milligram of ascorbic acid per 100 g of the sample (A0AC., 2006) [7].

$$\text{Vitamin C (mg/100g)} = \frac{\text{Ascorbic acid in standard} \times V_2 \times \text{Volume made up} \times 100}{V_1 \times \text{Aliquot taken} \times \text{Weight of the sample}}$$

Where
V_1 = Titre value of standard solution
V_2 = Titre value of sample

Non-enzymatic browning reaction (OD value)
Sample of five grams was soaked in 100 ml of 60 per cent alcohol for 12h and filtered. The absorbance reading of the filtrate was recorded at 440 nm using 60 per cent alcohol as blank in a spectrophotometer and expressed as optical density (OD) (Srivastava and Sanjeev Kumar, 2002) [8].

Microbial parameters of fortified extruded product
a. Standard plate count (CFU g^{-1})
One ml of each prepared sample was used for plating in duplicates from the required dilution, as defined by Ranganna (2008) [9], and after 15 or 20 ml of molten nutrient agar was poured aseptically into the plates. The content were mixed and plates were cooled. The plates were then inverted and incubated in an incubator maintained for 24 hours at 37±0.5 °C and the number of colony-forming units (CFU g^{-1}) was noted.

CFU g^{-1}= No. of colony X serial dilution ($10X10^{-8}$)

b. Yeast and mould count (CFU g^{-1})
As defined by Ranganna (2008) [9], 1 ml of suitable dilution prepared from each sample was used for duplicate plating, and 15 or 20 ml of molten PDA agar was then aseptically poured into the plates. The contents were mixed and plates were cooled. The plates were inverted and incubated for 3 days at 25±0.5 °C and the colony-forming unit (CFU g^{-1}) numbers were noted.
CFU g^{-1} = No. of colony x Serial dilution (10×10^{-2})

Organoleptic evaluation (9-point hedonic scale)
Organoleptic evaluation of extruded product was done by semi-trained panel of judges consisting of teachers and post-graduate students of College of Horticulture, Bengaluru. The organoleptic characteristics like colour/appearance, texture/mouth feel, taste, aftertaste and overall acceptability were evaluated on a 9-point hedonic scale (Ranganna, 2008) [9].

Results and Discussion
Moisture content (%)
The moisture content of the fortified RTE extruded snack increased to some extent during 3 months of storage period. It ranged between 3.04 to 3.35 for MBF+M (90.75% Best combination + 2.5% DMLP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) and 2.79 to 3.10 for snack MBF+T (90.75% Best combination + 2.5% DTP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) during 90 days of storage period (Table 1). The absorption of moisture by snack over the course of storage can be attributed to hygroscopic characteristics and porous structure of the product, storage environment (temperature, relative humidity) and type of packaging material. Jabeen *et al.* (2021) [10] reported an increase in moisture content in water chestnut flour incorporated corn- based extrudates during storage. Allai *et al.* (2022) [11] and Jabeen *et al.* (2021) [12] also reported similar increase moisture content in wholegrain based breakfast cereal and tomato pomace enriched corn extruded snack

during 120 days of storage period, respectively.

Water activity (a_w)

Water activity is an indicator of product stability and shelf life during post production period. The water activity of fortified RTE extruded snack increased during storage from 0.31 to 0.39 in MBF+M (90.75% Best combination + 2.5% DMLP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) and 0.29 to 0.38 in MBF+T (90.75% Best combination + 2.5% DTP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) is shown in Table 1. The increase in water activity of extrudates might be related to the humid environmental conditions leading the extrudates to absorb the moisture. A similar increase in water activity of extrude products during storage from 0.24 to 0.39 was reported by Allai *et al.* (2022) [10] in wholegrain based breakfast cereal. Dar *et al.* (2016) [6] and Haritha *et al.* (2014) [13] reported an increase in water activity in bran enriched extrudates (0.34-0.50) during six months of storage and garlic incorporated RTE extruded snack during two months of storage, respectively. Similar findings were reported by Nazir *et al.* (2017) [14] in apricot and date based extruded snack.

Vitamin C (mg/100g)

Vitamin C is an important constituent of nutrition and is used as additive in many food products because of its antioxidant capacity. Hence, it increases quality and nutritional value of the food. However, ascorbic acid is an unstable compound and under less desirable conditions it decomposes easily (Uddin *et al.*, 2002) [15]. The vitamin C content decreased during storage from 48.37 to 45.11 in MBF+M (90.75% Best combination + 2.5% DMLP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) and from 53.36 to 49.16 in MBF+T (90.75% Best combination + 2.5% DTP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) (Table 2). The results are in agreement with Dar *et al.* (2014) [16] who reported a similar decreasing trend of vitamin C (14.07 to 7.04 mg/kg) in carrot pomace based extrudates during 6 months of storage and Chikkanna *et al.* (2020) [17] in aonla and cereal based extruded RTE during 90 days of storage.

Non enzymatic browning (OD value)

Non-enzymatic browning is one of the most important chemical reactions responsible for quality changes during prolonged storage of dehydrated foods. Maillard reaction causes degradation of amino acids and affect the nutritional value of foods. The NEB in the fortified RTE extruded snack increased during the 90 days of storage period from 0.174 to 0.214 in MBF+M (90.75% Best combination + 2.5% DMLP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) and from 0.110 to 0.165 in MFB+T T (90.75% Best combination + 2.5% DTP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) (Table 2). The formation of brown pigments depends on temperature, the oxygen availability (packaging material) and duration of storage. Wani *et al.* (2020) [18] reported an increase in non-enzymatic browning in extruded snack during 90 days of storage.

Microbial population (CFU g^{-1})

The microbial load is an important parameter that manages the quality, safety and shelf life of the product. The fortified extruded products were microbially safe for 90 days under ambient conditions. It implies that the extruded product is safe for consumption. The absence of microbial load could be attributed to a combination of lower moisture content, lower water activity, and aluminium laminated polyethylene (ALPE) pouches. Similar findings were reported by Wani *et al.* (2020) [18] in extruded snack and Hussain *et al.* (2015) [19] in walnut fortified rice extrudate.

Sensory evaluation (9-point hedonic scale)

Sensory evaluation is a pivotal factor for consumer acceptability. Sensory score for colour/appearance, texture/mouthfeel, taste and overall acceptability of products declined gradually with the storage (Fig. 1). The overall acceptability of treatment MBF+M (90.75% Best combination + 2.5% DMLP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% 1.75% salt + 0.75% oil) showed a decrease in score from 8.41 to 8.11 and treatment MFB+T (90.75% Best combination + 2.5% DTP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil) exhibited a decrease in sensory value from 8.53 to 8.30 during 90 days of storage. Overall acceptability scores may decrease due to change in flavor, color and crispness of the extruded snack. Jabeen *et al.* (2021a) [10] and Alam *et al.* (2015) [20] reported decrease in overall acceptability from 4.36 to 3.74 during 120 days of storage in chestnut based extrudate and 87.73 to 72.98 during 180 days of storage in carrot pomace-chickpea incorporated rice based extruded snack, respectively.

Table 1: Effect of storage period on moisture content and water activity of fortified RTE extruded snack

Treatments	Moisture content (%)							Water activity (a_W)						
	Days of storage													
	0	15	30	45	60	75	90	0	15	30	45	60	75	90
MBF (30:60:10)	2.43	2.48	2.53	2.55	2.6	2.66	2.70	0.27	0.29	0.30	0.32	0.33	0.34	0.35
MBF+M (90.75:2.5)	3.04	3.10	3.14	3.19	3.25	3.29	3.35	0.31	0.32	0.33	0.35	0.37	0.38	0.39
MBF+T (90.75:2.5)	2.79	2.85	2.91	2.95	3.00	3.06	3.10	0.29	0.30	0.32	0.35	0.36	0.37	0.38
Mean	2.75	2.81	2.86	2.89	2.95	3.00	3.05	0.29	0.30	0.32	0.34	0.35	0.36	0.37
SE m±	0.008	0.010	0.013	0.010	0.011	0.013	0.011	0.007	0.007	0.006	0.007	0.006	0.006	0.005
CD @ 1%	0.038	0.049	0.061	0.05	0.051	0.065	0.049	0.030	0.033	0.029	0.031	0.029	0.026	0.024

MBF+M- 90.75% Best combination + 2.5% MLP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil

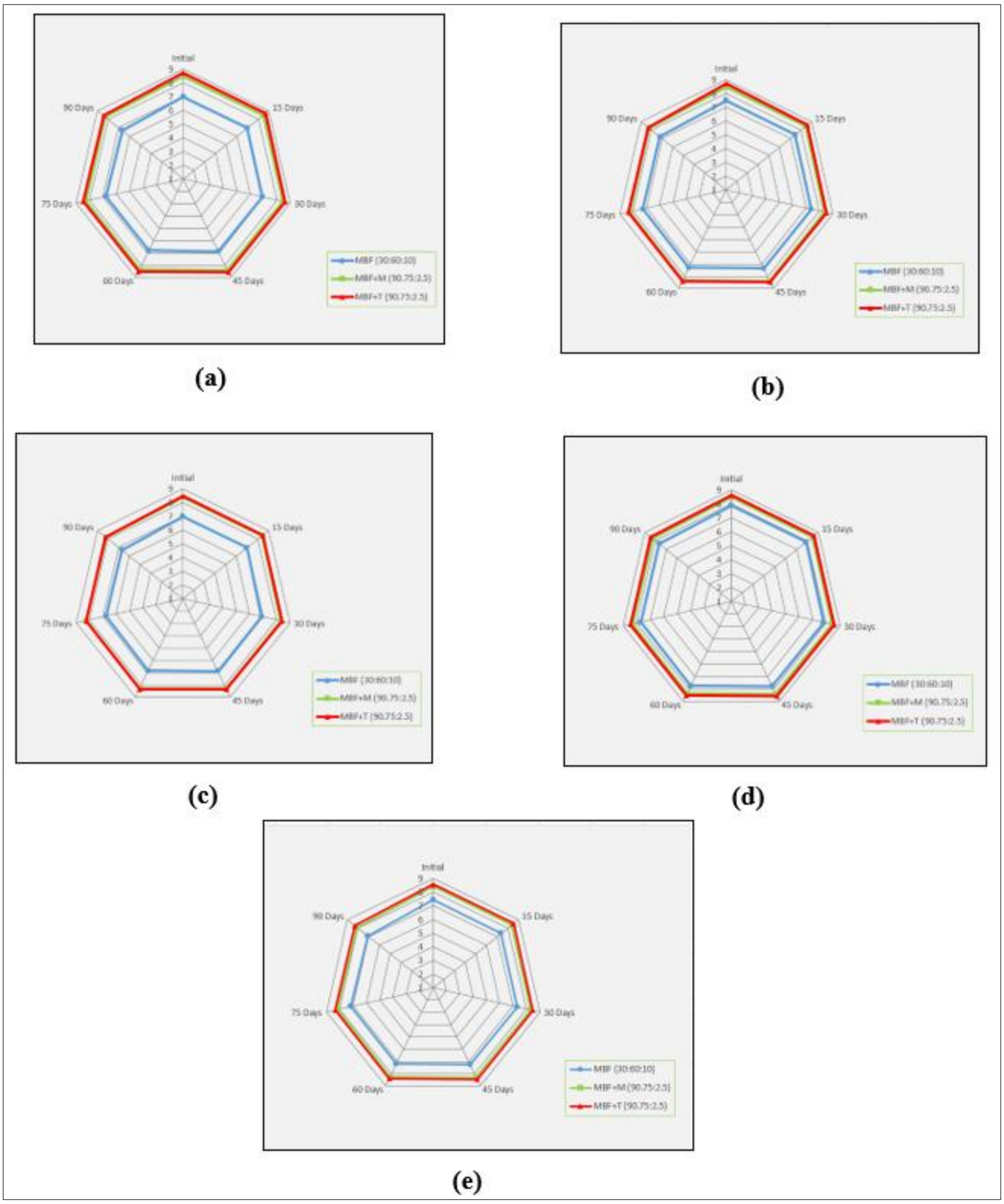
MBF+T- 90.75% Best combination + 2.5% TP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil

M- Maize grits, B- Banana flour, F- Foxtail millet grits, M- Moringa leaf powder, T- Tomato powder, DKP- Dehydrated kokum powder, OP- Onion powder, GP- Garlic powder, CP-Chilli powder and PP-Peri peri masala

Table 2: Effect of storage period on vitamin C content and non-enzymatic browning of fortified RTE extruded snack

Treatments	Vitamin C (Ascorbic acid mg/100g)							Non enzymatic browning (OD value)						
	Days of storage													
	0	15	30	45	60	75	90	0	15	30	45	60	75	90
MBF (30:60:10)	36.25	35.75	35.30	34.94	34.34	33.87	33.24	0.025	0.029	0.032	0.036	0.039	0.050	0.059
MBF+M (90.75:2.5)	48.37	47.86	47.33	46.85	46.16	45.67	45.11	0.174	0.180	0.185	0.195	0.199	0.201	0.214
MBF+T (90.75:2.5)	53.36	52.99	52.06	51.58	51.07	50.49	49.16	0.110	0.122	0.130	0.135	0.146	0.155	0.165
Mean	45.99	45.53	44.89	44.45	43.85	43.34	42.50	0.103	0.110	0.115	0.122	0.128	0.135	0.146
SE m±	0.36	0.33	0.35	0.41	0.39	0.37	0.35	0.003	0.004	0.004	0.003	0.005	0.004	0.003
CD @ 1%	1.69	1.65	1.68	1.98	1.91	1.73	1.57	0.014	0.02	0.019	0.013	0.015	0.019	0.013

MBF+M- 90.75% Best combination + 2.5% MLP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil
MBF+T- 90.75% Best combination + 2.5% TP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil
M- Maize grits, B- Banana flour, F- Foxtail millet grits, M- Moringa leaf powder, T- Tomato powder, DKP- Dehydrated kokum powder, OP- Onion powder, GP- Garlic powder, CP-Chilli powder and PP-Peri peri masala



MBF+M- 90.75% Best combination + 2.5% MLP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil
MBF+T- 90.75% Best combination + 2.5% TP + 0.5% DKP + 0.75% OP + 0.5% GP + 0.5% CP + 2% PP + 1.75% salt + 0.75% oil
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Fig 1: Effect of storage period on colour (a), texture (b), aftertaste (c), aftertaste (d) and overall acceptability (e) (9-point hedonic scale) of RTE raw banana flour fortified extruded snack

Conclusion

The study suggested that fortified extruded snack can be packed in ALPE pouches for up to 3 months under ambient storage condition without any microbial contamination. The changes in moisture content, water activity, non-enzymatic browning and vitamin C varied significantly during storage. During storage period moisture content, water activity and non-enzymatic browning increased, whereas, vitamin C and overall acceptability of extruded product decreased. Thus, RTE raw banana flour fortified extruded snack was safe for consumption during 90 days of storage in ALPE pouches under ambient storage condition.

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