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Shelf Life Evaluation of Fortified Soynut-Chikki using Different Packaging Materials

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A B S T R A C T

Fortified soynut-chikki was developed using de-oiled groundnut meal and puffed soynuts as one of the main ingredients to explore its nutritional benefits. Prepared Fortified soynut-chikki was stored in two different packaging materials *viz.*, PP (Polypropylene) and MP (Metalized polypropylene) packs to analyze the storability of fortified soynut-chikki at ambient condition (28±2°C). The microbial load, sensory characteristics (Overall acceptability scores), physico-chemical properties *viz.*, moisture content, water activity, FFA (Free Fatty Acid) values, color (L* values) and hardness of fortified soynut-chikki following each packaging materials such as (PP and MP) pack were also evaluated during storage period of 135 days at a frequency of 15 days at ambient condition. Metalized polyester (MP) pack was found to be most effective packaging material for better storability of fortified soynut-chikki having shelf life up to 120 days at ambient condition (28± 2°C).

Introduction

Peanut is one of the major oil seed-seeds of India and 80 percent of the produce is processed for oil and rest of de-oiled are either used as animal feed or as fertilizer. Therefore it is believed that it can help solve protein deficiency of malnourished population, and economics of "*Tel-ghani*" to sustain as a village industry. Groundnut meal and flour and co-products of groundnut after oil extraction have gained the importance for enhancing the product quality. Groundnut meal consists of about 6–8 percent oil, 35–45 percent crude protein, 6.5 percent crude fiber, 20–30 percent carbohydrate and 4–6 percent minerals (Desai *et al.*, 1999).

Fortification is a practice involves adding vitamins and minerals to commonly consumed foods during processing to increase their nutritional value. It is a proven, safe and cost-effective strategy for enhancing diets and for the prevention and control of micronutrient deficiencies. De-oiled groundnut meal flour still remains underutilized, and hence, research in this unexplored area will pave way to develop new value added products from this co-product, which is presently not being used for food

purposes frequently and as a result large scope are much available. Hence, fortification of puffed soynuts with edible quality de-oiled groundnut meal to prepare fortified soynut-chikki will help in better utilization of peanut meal as well as whole puffed soynuts and fulfilling the consumer's demand of nutritious products.

Since more consumers become more aware of its health benefits, it is becoming increasingly popular. Most of the popular chikkis, in addition to the most common peanut, can be prepared using groundnut kernels, Bengal gram, sesame seeds, pumpkin seeds, watermelon seeds, beaten rice, and copra (desiccated coconut), and some chikkis can be prepared with a combination of these elements. Cashew nuts, almonds, and pistachios are often used to create special chikkis despite the fact that they are somewhat expensive.

Processing and product diversification of puffed soynuts has caught lot of attention recently. Nutritional evaluation of puffed soynuts showed a significant decrease in phytates, tannins, trypsin inhibitors and oligosaccharides, a major anti-nutritional factors and a nutritive puffed soynuts was found to a good snacks. Like popped rice or corn, puffed soynuts too have a potential to be established in the market, especially to derive its nutritional benefits. The utilization of puffed soynuts for various preparation of chikki may help in increased consumption and thus nutritional security. These days nutritious chikki have become popular and exist in several types of high protein, high fiber and high calorie forms. They offer a fast, appropriate food source requiring modest preparation, with long shelf life and no refrigeration requirements. Depending on the ingredients used, manufacturing of these chikki bars is easy, and can be sold at very low price. Due to growing consumer demand for healthy, nutritious and convenient foods, attempts to improve the puffed soynuts's nutritional values as snack food by fortified with groundnut meal.

In the present study, de-oiled groundnut meal has been used as one of the ingredients due to its high nutritional value along with the other ingredients *viz.*, puffed soynuts and jaggery for the preparation of fortified soynut-chikki and evaluated for its storability by packing them in polypropylene (PP), Metallised Polyester (MP) storing them at ambient condition.

Materials and Methods

The ingredients used in the preparation of fortified soynut-chikki consist of de-oiled grounut meal obtained from 'Tel-Ghani', soybean (MAUS-612) variety was procured from Soybean Research Center, VNMKV, Parbhan (Maharashtra), salt, jaggery, liquid glucose, glycerin and packaging materials were procured from local market of Parbhani.

Preparation of fortified soynut-chikki

A small laboratory scale soynut-chikki making unit of 15 L capacity was used throughout the experiment for the preparation of fortified soynut-chikki. The fortified soynut-chikki was prepared at optimized process conditions at (60:40) jaggery:soynuts ratio, 25 g of de-oiled groundnut meal, at 35 rpm of chikki vessel and thickness of fortified soynut-chikki at 1 cm respectively.

The traditional method of peanut chikki preparation was followed for the fortified soynut-chikki preparation. Jaggery syrup was prepared by crushing jaggery block and heated in a chikki making unit vessel operating at the varying rpm 35 rpm till the hard crack stage will be developed at a temperature of approximately 115-118^{0}C to check the soft ball consistency. Liquid glucose was mixed which adds glossiness to the finished fortified soynut-chikki. Further other ingredients such as jaggery:soynuts in ratio 60:40 and quantity of de-oiled groundnut at 75 g were further added and mixed uniformly. The hot mass was transferred to pre greased (using glycerin) tray and spread uniformly with help of a roller and cut into uniform thickness of 1 cm, respectively and allowed to cool at room temperature packed in Polypropylene (PP) and Metallised Polyester (MP)

packs. Each of above ingredients were required for making 1kg of fortified soynut-chikki in batch. The quality parameters such as microbial load such as SPC(Standard Plate Count) and yeast and mold count, Organoleptic characteristics (Overall acceptability scores), physico-chemical properties *viz.*, moisture content, water activity, FFA (Free Fatty Acid) values, color (L* values) and textural characteristics (hardness) of fortified soynut-chikki following each packaging materials i.e. (PP and MP) pack were also evaluated.

Quality parameters of fortified soynut-chikki in different packaging materials during storage

SPC (Standard Plate Count) and yeast and mold count

Microbial analysis of fortified soynut-chikki was carried out as per the method cited in Indian Standard Institute (ISI, 1969)

Moisture content and FFA (Free Fatty Acid) values

Moisture content and FFA (Free Fatty Acid) were estimated by the method of AOCS (2005).

Textural Characteristics

The textural properties (Hardness) of fortified-soynut chikki samples were evaluated using texture analyser (TA.XT. Plus Texture Analyser, Stable Micro System, UK) fitted with P/75 cylindrical probe. The test was performed using a load cell of 50 kg, pre-test speed of 1 mm/s, test speed of 0.5 mm/s, distance of 10 mm, trigger force of 0.20 N. Mean peak compression force recorded and hardness value was expressed in kg as per the procedure of Gupta *et al.,* (2007),

Water activity and Color value

Water activity and color (L* value) of fortified soynut-chikki was measured using water activity meter and hunter colorimeter.

Sensory Evaluation

Sensory evaluation of fortified-soynut chikki was evaluated in terms of OAA (Overall Acceptability) scores on a nine-point hedonic scale. 9 = Like extremely, 8 = Like very much, 7 = Like moderately, 6 = Like slightly, 5 = neither like nor dislike, 4 = Dislike slightly, 3 = Dislike moderately, 2= Dislike very much and 1 = Dislike extremely. Samples were randomly drawn from each experimental block, coded and served to the panellists randomly and were asked to grade based on 9 point Hedonic scale (Larmond, 1977).

Statistical Analysis

The data analysis was performed using statistical software (SPSS Statistics, Version 25.0) IBM Corp. (2017)

Results and Discussion

Effect of Microbial load of fortified soynut-chikki during storage

It was observed from Table 1 that there was no initial microbial load in terms of SPC in both packaging materials. Afterwards in case of PP pack SPC was observed after 15 days and in MP pack it was observed at 30 days of storage interval. In PP pack it was increased from 1 to 53 cfu/g up to 105 days and in case of MP pack, SPC it was increased from 2 to 55 cfu/g for 135 days, respectively during the storage at ambient combination. According to Prevention of Food Adulteration Act (1954) the microbial load permissible limit is up to 50000 CFU/g. From table 1, it was observed that the permissible limit crossed at 105 days in PP pack and 135 days in MP pack. Therefore, the shelf life was considered for fortified soynut-chikki packed in PP pack as 90 days and MP pack at 120 days.

Therefore, microbiological analysis of developed fortified soynut- chikki was performed up to 90 days in PP pack and 120 days in MP pack. On the basis of limit of microbial load further physico-chemical

analysis, sensory properties, color and textural properties of fortified soynut-chikki were analyzed.

Fig.1 illustrates that, fortified soynut-chikki packed in PP pack the rate of SPC was higher compare to MP pack. It is safe up to 90 days in PP pack and 120 days in MP pack. These might be possible due to development of fortified soynut-chikki under hygienic conditions, puffing at adequate temperature, low oxygen and moisture transmission rate of MP pouch packaging material. Similar finding was observed by Padmashree *et al.,* (2013). Farajzadeh and Golmakani (2011) also reported that popped Amaranth chikki was suitable to consume up to 4 months storage period at ambient temperature.

Yeast and mould count

Yeast and mold growth in fortified soynut-chikki was not observed in both the packaging materials packed in PP and MP pack initially. It was observed at 45 days in PP pack and at 60 days in MP pack. As per the specification by Food Administration Manual recommended, the associated yeast and molds count should be below 1000 cfu/g. From Table 2, it was observed that the permissible limit for yeast and mold growth count in case of PP pack and MP pack were within range at 90 days and 120 days respectively.

From Fig. 2, it was noted that fortified soynut-chikki packed in PP pack, the rate of Yeast and Mould count was greater than MP pack. Therefore, MP pack packaging material was found superior than PP pack and safe for consumption by consumer. Similar observations were recorded by Singh *et al.,* (2021) that the developed popped pearl millet bar is consumable and safe for consumers till 120 days storage period.

Organoleptic changes of fortified soynut-chikki during storage

The shelf life of any food material depends upon the consumer's overall sensory characteristics which is determined by overall acceptability scores.

The shelf life of fortified soynut-chikki in two different packaging materials *i.e.* PP and MP pack were analyzed organoleptically at regular interval of 15 days and changes in its Overall Acceptability (OAA) scores are given in Table 3. Table 3 showed a uniform decrease in the overall acceptability during storage. As regards to Overall Acceptability Score (OAA) scores, highest mean score (8.5) obtained by fortified soynut-chikki at 0 days of storage which had gradually decreased up to 6.0 on PP pack and 7.8 in MP pack, respectively. After 120 days the samples were disliked by the judges due to loss of overall sensory properties, hence the samples were discarded by judges.

The lower overall acceptability score in PP packed fortified soynut-chikki is may be due to poor permeability of moisture in PP pack. Similar findings were reported by Padmashree *et al.,* (2013) for flax-oat nutty bar.

From the Fig. 3, It was noted that fortified soynut-chikki packed in MP pack can be stored up to 120 days without affecting the sensorial parameters. However, its score was slightly decreased and liked moderately in PP pack stored up to 90 days. The minimum OAA score in PP pack may be due to poor gas permeability of packaging material Kumar *et al.*, (2017).

Physico-chemical changes of fortified soynut-chikki during storage

Changes in physico-chemical properties of fortified soynut- chikki such as moisture content, water activity and (FFA) Free Fatty Acid (% oleic acid), color (L* value) and textural properties (hardness) were determined during storage period with frequency interval of 15 days stored in two different packaging materials *i.e.* PP (Polypropylene) and MP (Metalized polyester) pack.

Moisture content

Moisture content has an important role in determining the storage stability as it determines the

quality and stability of any food product. Generally, moisture content decreases or increases during storage depending upon the storage condition and packaging material used.

From table 4, during 135 days of storage, fortified soynut-chikki packed in PP packaging materials exhibited an increases in moisture content from 4.39 % to 7.90 % and 6.30 % in MP pack at ambient conditions respectively. In PP packed fortified soynut-chikki, the crunchy texture of fortified soynut chikki was observed up to 5.81 % moisture content at 90 days; afterwards the fortified soynut-chikki lost its crisp and crunchy texture resulting in sticky and soggy surface. However, the fortified soynut-chikki stored in MP pack retained its textural properties after 120 days of storage period at moisture content of 5.88 %. The increase in moisture content during storage could be due to the fact that MP pack has better moisture barrier properties as compared to PP pack and PP pack being high in water vapor transmission rate contributed significantly to the increase in moisture content of fortified soynut chikki. Similar findings were described by Sunkireddy, (2011) for protein rich bar with flaxseed. Fig. 4 shows that, the rate in increase of moisture content was more pronounced in fortified soynut-chikki stored in PP pack as compare to fortified soynut-chikki packed in MP pack, respectively. These results suggested that MP packaging material played a profound role in preventing the migration of water in fortified soynut-chikki. Similar observations were also in consistent with Padmashree *et al.,* (2018) for choco-quinoa nutria bars packed in PP films and Hirdyani and Charak (2015) for chikki developed with pepita.

Water activity (a_w)

Water activity is an important factor affecting the stability of food material. Controlling water activity during storage maintains proper structure, texture and prevents growth of microbes in food materials. From table 5, it was found that the water activity of the fortified soynut-chikki in PP packaging ranged from 0.475 to 0.695 and 0.682 in MP packaging during 135 days storage period. According to Singh *et al.*, (2021) and Loveday *et al.*, (2009) reported that protein bars are generally formulated to have a_w values less than 0.65 and moisture content between 10-15 % (w/w). This means that in this study, fortified soynut-chikki packed in PP and MP packs was within the safe level of water activity and moisture content. From the table 5, it is revealed that beyond 90 days, the water activity of fortified soynut-chikki stored in PP pack was 0.695 which exceeds the permissible range. Hence, fortified soynut-chikki was acceptable up to 90 days in PP pack and 120 days in MP pack.

From Fig. 5, it was revealed that PP pack exhibited higher water activity than MP pack. This may be possibly due to the change in temperature and humidity of the surrounding environment which increases the moisture content of fortified soynut-chikki. Similar pattern of increasing trend was reported by Padmashree *et al.*, (2018) choco-quinoa nutria bar. Banach *et al.*, (2016) also recorded increase in water activity in nutritious milk protein concentrate chikki during storage.

Free fatty acid (FFA)

Table 6 showed that, the free fatty acid (% oleic acid) values of fortified soynut-chikki was increased with increase storage period for both the packaging materials. The changes in free fatty acid content depend on initial moisture content, storage conditions (temperature and humidity) and also packaging material used (Fritsch and Heermann, 2011). In this study the moisture content of fortified soynut-chikki was found lower and within the limit.

Table.1 Standard plate count (cfu/g $\times 10^{-3}$) of fortified soynut-chikki during storage

Packaging materials	Storage period (days) at ambient temperature									
	0	15	30	45	60	75	90	105	120	135
PP	NP	1	3	9	15	24	45	53	ND	ND
MP	NP	NP	2	5	10	17	26	38	48	55

Analysis of variance				
Source	MSS	F-value	S.E.	C.D.
Packaging Materials (P)	256.21	226.22*	0.338	1.124
Storage days (D)	175.69	155.69*	0.181	0.525
P x D	133.56	110.65*	0.554	1.588

* 5 % level of Significance NP- Not present ND- Not determined

Where,

PP: Fortified soynut-chikki packed in Polypropylene pack

MP: Fortified soynut-chikki packed in Metalized polyester pack

Table.2 Yeast and mould count (cfu/g $\times 10^{-1}$) of fortified soynut-chikki during storage

Packaging materials	Storage period (days) at ambient temperature								
	0	15	30	45	60	75	90	105	120
PP	NP	NP	NP	10	13	20	32	ND	ND
MP	NP	NP	NP	NP	4	7	12	18	29

Analysis of variance				
Source	MSS	F-value	S.E.	C.D.
Packaging Materials (P)	187.26	158.81*	0.20	0.57
Storage days (D)	336.600	285.456	0.44	1.27
P x D	153.48	130.16*	0.63	1.80

* 5 % level of Significance NP- Not present ND- Not determined

Table.3 Changes in overall acceptability of fortified soynut-chikki during the storage

Packaging material	Storage period (days) at ambient temperature									
	0	15	30	45	60	75	90	105	120	135
PP	9	9	8.7	8.7	8.5	8.3	8	7.6	7.2	6.9
MP	9	9	8.9	8.8	8.8	8.6	8.6	8.3	8.1	7.8

Analysis of variance				
Source	MSS	F-value	S.E	C.D
Packaging Materials (P)	12.24	1940.60*	0.01	0.04
Storage Interval (D)	0.81	126.95*	0.03	0.09
P x D	0.27	41.95*	0.05	0.13

* 5 % level of Significance

Table.4 Moisture content of fortified soynut- chikki during storage

Packaging materials	Storage period (days) at ambient temperature									
	0	15	30	45	60	75	90	105	120	135
PP	4.32	4.36	4.41	4.49	4.88	5.31	5.81	6.45	7.12	7.90
MP	4.32	4.34	4.38	4.42	4.65	4.90	5.16	5.51	5.88	6.30
Analysis of variance										
Source	MSS		F value		S.E.		C.D.			
Packaging Materials (P)	35.65		1959.49*		0.02		0.07			
Storage days (D)	1.75		96.16*		0.05		0.16			
P x D	0.89		49.20*		0.08		0.22			

* 5 % level of Significance

Table.5 Water activity (%) of fortified soynut- chikki during storage

Packaging materials	Storage period (days) at ambient temperature									
	0	15	30	45	60	75	90	105	120	135
PP	0.475	0.479	0.489	0.501	0.541	0.611	0.639	0.695	ND	ND
MP	0.475	0.475	0.483	0.492	0.505	0.547	0.569	0.598	0.622	0.682
Analysis of variance										
Source	MSS		F value		S.E.		C.D.			
Packaging Materials (P)	0.27		61.569*		0.027		0.08			
Storage days (D)	0.24		53.392*		0.012		0.03			
P x D	0.09		21.617*		0.039		0.11			

* 5 % level of Significance ND- Not Determined

Table.6 Free fatty acid (% oleic acid) of fortified soynut-chikki during storage

Packaging materials	Storage period (days) at ambient temperature									
	0	15	30	45	60	75	90	105	120	135
PP	0.51	0.56	0.62	0.71	0.83	0.98	1.17	1.35	1.56	1.72
MP	0.51	0.54	0.58	0.64	0.71	0.8	0.91	1.04	1.19	1.32
Analysis of variance										
Source	MSS		F-value		S.E.		C.D.			
Packaging Materials (P)	5.07		37618.85*		0.002		0.006			
Storage days (D)	0.23		1681.90*		0.005		0.014			
P x D	0.06		438.61*		0.007		0.019			

* 5 % level of Significance

Table.7 Color (L* value) of fortified soynut-chikki during storage

Packaging materials	Storage period (days) at ambient temperature									
	0	15	30	45	60	75	90	105	120	135
PP	59.95	59.90	57.20	52.95	49.11	44.25	40.98	33.21	30.01	25.06
MP	59.95	59.92	59.01	58.22	55.69	53.03	50.11	46.23	42.49	38.12
Analysis of variance										
Source	MSS		F-value		S.E.		C.D.			
Packaging Materials (P)	4,339.74		26266.30*		0.07		0.21			
Storage days (D)	223.50		1,352.72*		0.17		0.48			
P x D	54.13		327.63*		0.23		0.67			

* 5 % level of Significance

Table.8 Changes in hardness (kg) of fortified soynut-chikki during storage

Packaging materials	Storage period (days) at ambient temperature									
	0	15	30	45	60	75	90	105	120	135
PP	28.1	29.78	30.05	32.22	34.98	36.85	38.94	42.01	47.22	53.59
MP	28.1	28.94	29.25	30.23	31.55	32.85	33.43	34.88	35.91	38.44
Analysis of variance										
Source	MSS		F-value		S.E.		C.D.			
Packaging Materials (P)	1190.91		7958.25*		0.07		0.20			
Storage days (D)	106.73		713.24*		0.16		0.45			
P x D	35.95		240.22*		0.22		0.64			

* 5% level of Significance

Fig.1 Effect of different packaging materials on changes in SPC (Standard Plate Count) during storage of fortified soynut-chikki

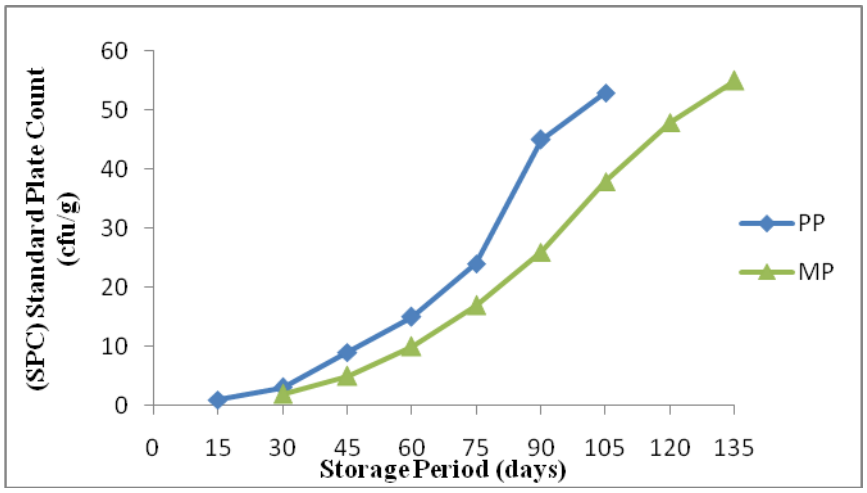


Fig.2 Effect of different packaging materials on changes in Yeast and Mould Count during storage of fortified soynut-chikki

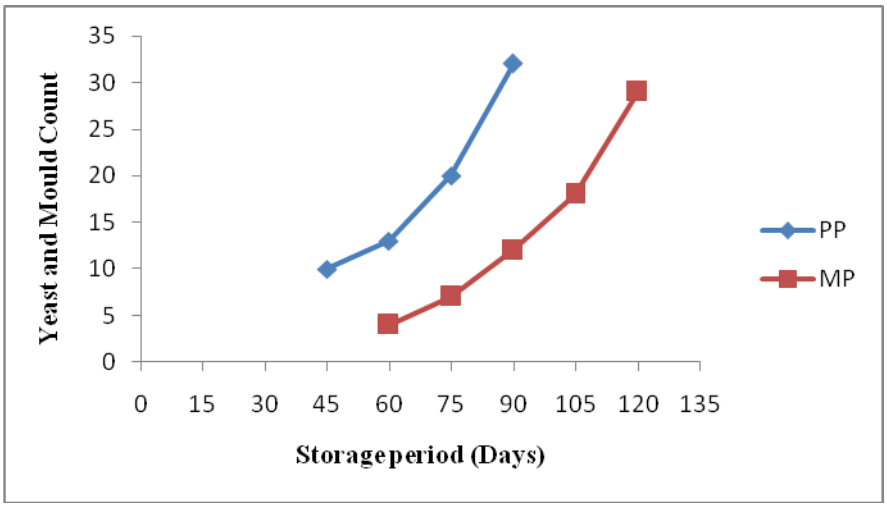


Fig.3 Effect of different packaging materials on changes in overall acceptability during storage of fortified soynut-chikki

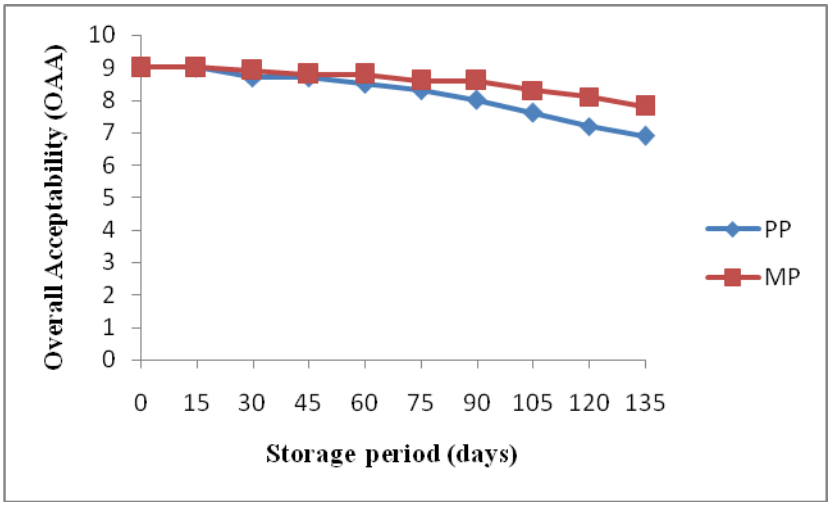


Fig.4 Effect of different packaging materials on changes in moisture content during storage of fortified soynut-chikki

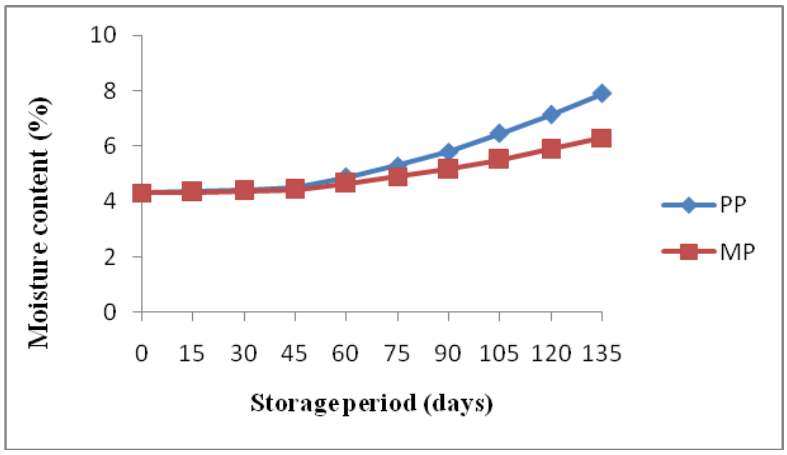


Fig.5 Effect of different packaging materials on changes in water activity during storage of fortified soynut-chikki

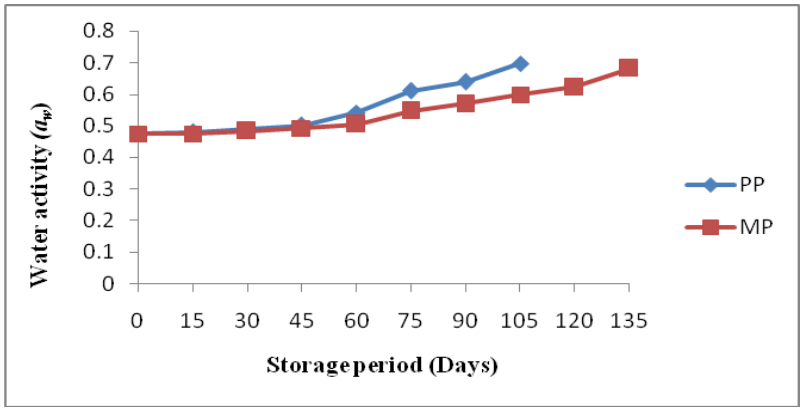


Fig.6 Effect of different packaging materials on changes in FFA during storage of fortified soynut-chikki

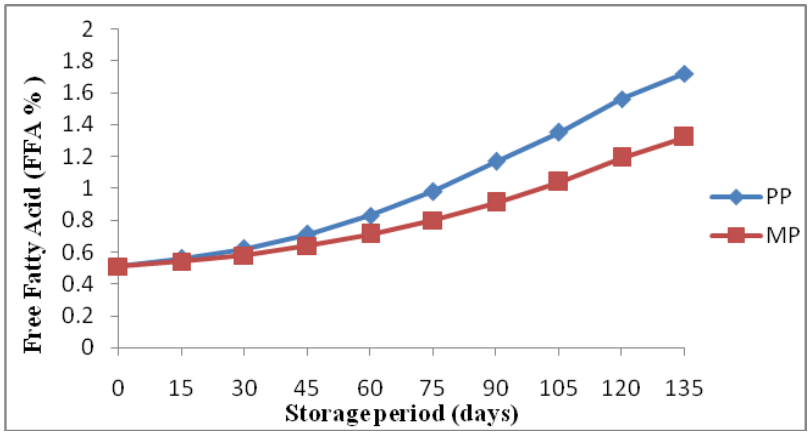


Fig.7 Effect of different packaging materials on changes in color (L* value) during storage of fortified soynut-chikki

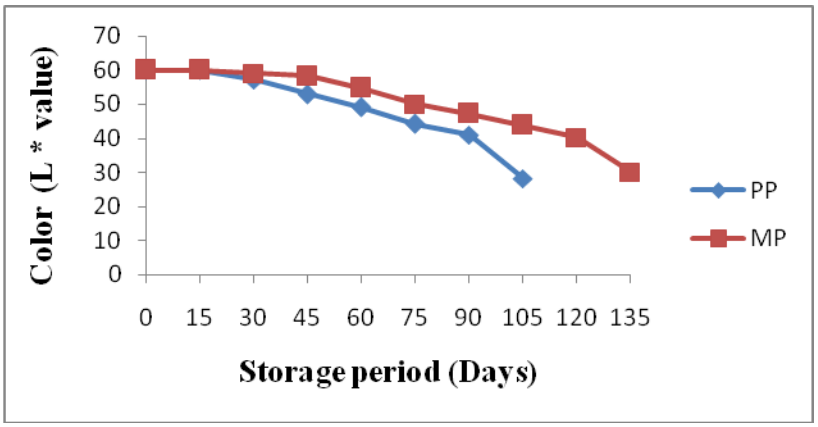
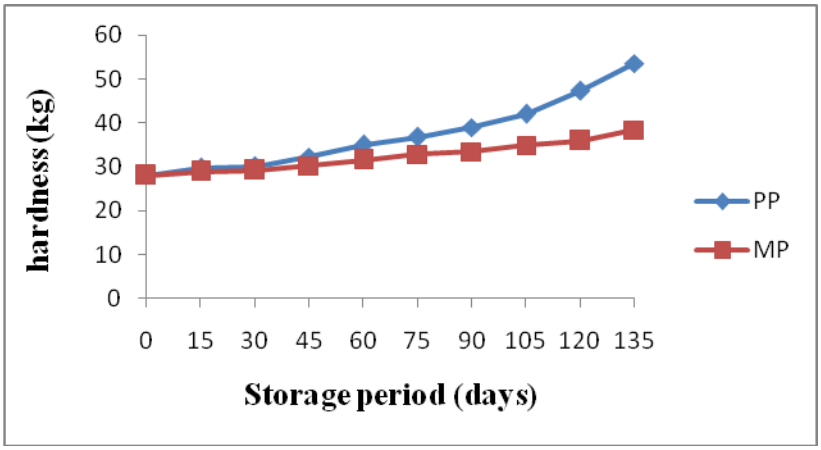


Fig.8 Effect of different packaging materials on changes in hardness (kg) during storage of fortified soynut-chikki



Initially, the free fatty acid (% oleic acid) value of fresh fortified soynut-chikki was recorded 0.51 %. During storage the FFA values varied from 0.51 to 1.72 % and 1.32 % in PP and MP pack, respectively at end of 135 days of storage interval. The increased in FFA (%) values for fortified soynut-chikki was due to degradation products of hydro peroxides which is directly related with moisture and relative humidity of the products. Similar results were also described by (Sowbhagya and Bhattacharya, 1976). Though it was increasing in both packaging materials, it was organoleptically accepted as we had added de-oiled groundnut meal powder which contains less oil and increases in FFA (%) values were noted within limit. Muttagi *et al.*, (2014) observed similar findings for sunflower kernel chikki in which FFA (%) increased from 0.61 to 1.57 during 60 days of storage.

The results comprehending the increase in of free fatty acids throughout shelf-life study in different packaging materials is consistent with the findings of Jeyarani *et al.*, (1997) who stated that free fatty acids increased from 0.98 to 1.1 in storage-life study of 150 days, though legume based sweet bars were kept at ambient room temperature.

From Fig, 6, it was observed that the FFA (%) for fortified soynut-chikki formation stored in PP pack was greater than MP packed fortified soynut-chikki.

This may be due to low oxygen barrier property of PP pouch and oxidation and hydrolysis of fat content of raw materials Similar findings were also obtained by Singh *et al.,* (2021) during the storage of popped peal millet bar.

Color (L* value)

Color is an important quality parameter that plays a crucial role in taste and perception of the food. It provides idea for the consumers about freshness, appearance and overall quality of the finished product. These effect a consumer decision to purchase that product.

The color (L* value) represent the lightness (100) to darkness (0) spectrum. From Table 7, at day zero, fortified soynut-chikki showed lighter color as indicated by L* value of 59.95. It varied from 59.95 to 25.06 in PP pack and in MP pack; it varied from 59.95 to 38.12 at the end of 135 days of storage. Overall the color (L* value) of fortified soynut-chikki decrease during storage, especially in PP packaging materials. After 90 days, there is slight drop in color of fortified soynut-chikki because as storage days increases, there is slight accumulation of moisture on surface and therefore, surface color changes and that moisture is due to migration from surrounding atmosphere as well as physic-chemical changes due to microbial load beyond the limit.
The decreased in color (L* value) i.e lightness was reduced, might be related to enzymatic and non-enzymatic browning, which occurred during storage. Similar observation was by Aigster *et al.,* (2011) for granola bars and cereal bars.

It is evident from the Fig. 7, that the fortified soynut-chikki stored in PP pack have slightly lower L* values, which in turns higher rate of browing of fortified soynut-chikki at the end of 90 days of storage. While in case of fortified soynut-chikki stored in MP pack the observed L* value was slightly lighter at end of 120 days of storage period. Therefore the result indicated that MP pack showed higher preventive effect on color of fortified soynut-chikki than PP pack during storage. Khan *et al.,* (2008) illustrated similar reports in groundnut burfi samples.

Textural characteristics of fortified soynut-chikki during storage

The textural characteristics are one of the key factors which influence the overall product acceptability. Physico-chemical changes among the ingredients in fortified soynut-chikki can occur over time and begin to affect the texture of the product.

Hardness (kg)

The hardness of fortified soynut-chikki was measured by Textural Analyzer (TA.XT Plus). The texture analyzer results revealed that initially fresh fortified soynut-chikki sample has less hardness in both PP and MP pack which increased from 28.1 to 53.59 kg in PP pack and 28.1 to 38.44 kg in MP pack, respectively with storage time. From the table 8, it was observed that comparatively hardness of fortified soynut-chikki stored in PP pack was increased faster than MP pack.

After 90 days of storage in PP pack, hardness of fortified soynut-chikki drastically. This phenomenon was related to slight increase in moisture content and water activity limit (from Table 4 and 5). Increased moisture content after 5.81 % and water activity limit beyond 0.639, texture of fortified soynut-chikki become harder which adversely affect the shelf life. From Table 4, water activity data helps to establish a cut-off point of hardness values of fortified soynut-chikki at the 90 days in PP pack and 120 days in MP packed, respectively. Until this point, texture of fortified soynut-chikki was still crunchy, crisp and less tough.

Simón *et al.,* (2010) reported that the shelf life of a protein energy bar often limited by development of a hard texture that consumer find unacceptable for consumption. Similar results were obtained in the present studies. The development of hard texture during storage may be attributed to thiol-disulphide interchange reaction during storage which leads to

protein cross linking aggregation and network formation.

The hard texture development in fortified soynut-chikki also may be due to migration as well formation of ordered secondary structure and lower surface hydrophobicity of protein particles. Similar results were also studied by Simon *et al.,* (2009). Besides this, milliard reaction between reducing sugar of jaggery and lysine content residue plays a part in the hardening of a protein bar Gerard (2002). McMahon *et al.,* (2009) reported similar findings of increase in hardness of high protein nutritious whey protein isolates bar during storage at ambient temperature.

From Fig. 8, it was revealed that in PP packed fortified soynut-chikki the hardness were greater compare to fortified soynut-chikki stored in MP pouch indicating that PP pack is less suitable for packaging of fortified soynut-chikki. Similar observation were noted by Padmashree *et al.,* (2018) in choco-quinoa nutria bar and Pallavi *et al.,* (2015) in fruit and nut cereal bar during storage at ambient condition.

A nutrient rich chikki can be prepared by incorporation of de-oiled groundnut meal and puffed soynuts to enhance its protein content. Fortified soynut-chikki packed in PP (Polypropylene) pack underwent deterioration at a slightly faster rate as compared to the fortified soynut-chikki packed in MP (Metalized Polyester) pack stored at ambient condition. Therefore MP (Metalized Polyester) pack was found to be most effective packaging material for better storability of fortified soynut-chikki having shelf life up to 120 days at ambient condition (28± 2°C).

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