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Sensory and Keeping Quality of a Ready-to-Eat Snack Incorporated with Pre-treated Soy Flour

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ABSTRACT

The objective of this study was to investigate the effect of incorporating pre-treated soy flour on fat uptake and keeping quality of a ready-to-eat wheat-based snack. Defatted soy flour was pre-treated with partial enzyme hydrolysis or thermal treatments (using microwave and dry heat) for incorporation at a 20% level to the basic product. Products prepared without defatted soy flour and with untreated soy flour served as two controls for comparison. The prepared products were analyzed for fat uptake and stored in polyethylene terephthalate (PET), metallized foil (MF), low-density polyethylene and steel containers at room temperature (27°C) in open shelves for one month to study the shelf life. One product was stored at low temperature (4°C). All products were analyzed at weekly intervals for free fatty acids (FFA), peroxide value (PV) and sensory attributes. Results indicate that incorporation of soy flour decreased fat absorption in products at varying levels ranging from 9.3% to 29.4%. The extent of reduction was highest in the product with untreated soy flour. The sensory quality of soy flour-incorporated product was comparable to the control. Pre-treatment of soy flour with enzyme trypsin lowered the sensory quality of the product, but thermal treatment improved the scores. On storage, some of the products developed an off-flavour at the end of the 2nd week as assessed by sensory evaluation. The addition of defatted soy flour decreased FFA and PV in stored products. Among different packaging containers MF and PET were better with a lower FFA and PV.

Keywords: enzyme hydrolysis, free fatty acids, microwave heating, oil uptake, peroxide value, thermal treatment

Abbreviations: ANOVA, Analysis of variance; **CP**, control product; **FFA**, free fatty acid; **LDPE**, low density polyethylene; **MF**, Metallized foil; **PET**, polyethylene terephthalate; **PV**, peroxide value; **SC**, soy control; **SDH**, soy dry heat; **SET**, soy enzyme treated; **SMW**, soy microwave

INTRODUCTION

Deep-frying is one of the oldest methods of processing and is used extensively by the food industry, as well as by the domestic sector worldwide. Fried foods are concentrated sources of energy and fat. Deep fried foods are shelf stable and organoleptically score higher due to their crispy and crunchy texture. They constitute a major share of convenience foods industry in the form of ready-to-eat snacks (Pradeep *et al*. 1999). Some of the advantages of frying are common to all heat processes, while others are specific to it alone. In general, deep-frying destroys bacteria and toxins and makes food more palatable (Varela 1988).

Consumption of deep fried foods as snacks continues to increase worldwide. At the same time an awareness regarding healthy eating is also increasing among consumers. Consumption of excess fat in the diet has been linked to coronary heart disease (Williams and Mittal 1999). Production of oxidized lipoproteins in deep fried foods is believed to play an important role in the development of atherosclerosis (Lake and Scholes 1997). In order to meet the recent trends and consumer demand for low fat products, there exists a need for reducing oil uptake during deep fat frying without compromising the sensory quality of products.

Most new low fat fried products include fat substitutes in the formulation; however, these are limited to baked products. Another approach is the use of edible ingredients in the batter and breading mix to improve coating performance (Duxbury 1989). Various ingredients such as powdered cellulose (Pinthus *et al*. 1993), methylcellulose (Williams and Mittal 1999) and soy protein isolate (Martin and Davis 1986) have been used. The use of proteins (such as milk powders, egg albumin) as ingredients in fried products is also known (Pradeep *et al*. 1999). Yet their functionality as edible coating to reduce oil uptake by deep-fried foods have not been established. Limited research work has been done on the aspect of use of proteins and hydrocolloids as an ingredient to reduce oil uptake in deep fried foods (Mallikarjuna *et al*. 1997).

The oil pickup during frying is known to be a function of the surface tension and hydrophobicity of the product being fried. These properties of proteins are altered during hydrolysis. It is perceived that hydrolysis of proteins may alter the surface tension and hydrophobicity in a manner which would manifest itself as a decrease in the oil uptake during deep fat frying (Pradeep *et al*. 1999).

Lipid oxidation at higher temperatures in the presence of oxygen and steam as encountered in deep fat frying produces many compounds, which exert desirable and undesirable effects on food flavour and quality. Oxidative and chemical changes taking place in fats during frying are characterized by a decrease in total unsaturation of the fat with an increase in FFA, foaming, color, viscosity, polar and polymeric materials, etc. (Stephen *et al*. 1978). Most of the FFA found in frying fats result from hydrolysis of the frying oil by steam generated by interaction of the food product with the hot oil (Stevensen *et al*. 1984). The peroxide value primarily indicates the overall quality of oil during frying and after storage (Paul and Mittal 1996).

The objective of the present study was to study the effect of incorporation of pre-treated soy flour on oil uptake, keeping quality and sensory attributes of a wheat-based deep fried snack. The pre-treatments chosen for the soy flour were partial enzyme hydrolysis and two types of thermal treatments, namely microwave and dry heat.

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MATERIALS AND METHODS

Procurement of raw materials

The food ingredients required for the study namely, refined wheat flour (*Triticum aestivum*), sunflower oil (*Helianthus annuus*), omum (*Trachyspermum ammi*) and salt were purchased from a local market. Defatted soy flour (*Glycine max Merr.*) was procured from Shakti Sugar Mills, Coimbatore, India. Chemicals used for the entire study, namely, sodium thiosulphate, sodium hydroxide, oxalic acid, phenolphthalein, soluble starch, hydrogen chloride, sulphuric acid, potassium permanganate, potassium iodide, ethanol, petroleum ether (60-80°C), chloroform, and glacial acetic acid were AR-Grade and procured from Sd Fine Chemicals and Qualigens Co. Ltd, Mumbai, India. Glass double distilled water was used for the entire analysis. All results presented are an average of duplicate analysis of each sample.

Preparation of product

The product chosen for the study was a wheat-based ready-to-eat deep fried snack known as 'Diamond cuts'. The basic recipe was as follows – a stiff but pliable dough was prepared using wheat flour (87%), heated and cooled sunflower oil (10%), salt (2%), omum (1%) and water. It was rolled into a 5 mm-thick sheet and cut into diamond shapes with a knife and deep-fried in hot sunflower oil at a temperature of 173 ± 1°C for 5 min till the development of a very light brown colour. The ratio of product to oil was 1:2. For each batch, 500 g of raw material and one liter of oil was used and the total frying time was 60 min. The oil was not replenished during frying and it was not reused. After frying, the products were spread on a steel sieve to drain excess oil for 15 min and packaged immediately after cooling. This was used as the 'control product' (CP). All products, two control and three experimental were fried separately using fresh oil.

For the experimental products, a part of wheat flour was replaced with either treated or untreated soy flour. Defatted soy flour was used at 20% level after many initial pilot trials for standardizing the recipe. The different types of pretreatments used for defatted soy flour before incorporation were partial enzyme hydrolysis and thermal treatments as given below. Products prepared by incorporating untreated soy flour served as soy control (SC).

Pretreatments used for soy flour

Enzyme hydrolysis

A slurry of defatted soy flour and water (in a ratio of 1:10) was prepared and incubated at 50°C for 10 min. It was treated with trypsin solution (concentration 0.3% of the weight of flour to get an enzyme:substrate ratio of 1:200) and incubated further for about 40 min. After incubation the enzyme was inactivated by gelatinizing the batter at 98°C, cooled and used with wheat flour to prepare the dough as given in the basic recipe and the product was prepared (soy enzyme treated, SET).

Thermal treatment in microwave

For microwave treatment, defatted soy flour was exposed to microwave heat. 100 g of defatted soy flour was placed in a glass dish and spread evenly. It was heated in a microwave for a total of 4 min with intermittent stirring every minute to avoid scorching of the flour. This was incorporated into basic dough at a 20% level to prepare the product (soy microwave treated, SMW).

Dry heat treatment

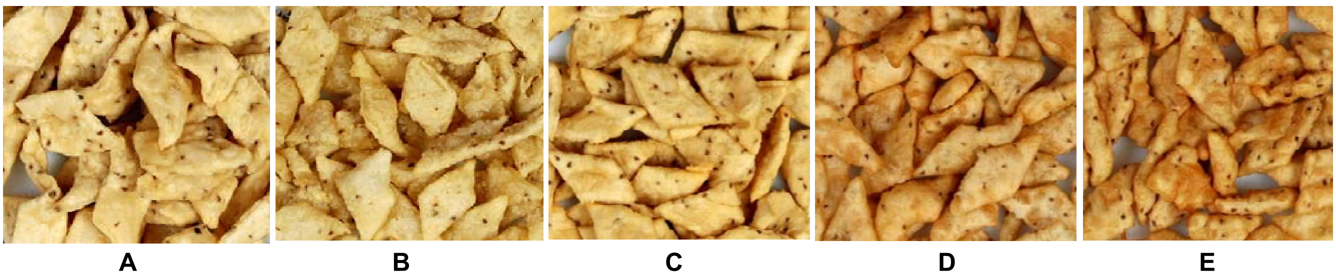
Defatted soy flour was placed in an airtight steel container and kept in a pressure cooker. It was heated under steam pressure for 8 min. No water or steam entered the container while heating. After heating, defatted soy flour was cooled without removing the lid of the container. This was used for incorporation at a 20% level to prepare the product (soy dry heat treated, SDH).

Storage study

Each set of products was stored in four different packaging containers namely, polyethylene terephthalate (PET), metallized foil, low-density polyethylene (LDPE) and steel at room temperature (27°C). In addition, one set packed in LDPE was stored at low temperature (under refrigeration, at 4°C) for the purpose of comparison. Samples were drawn at one-week intervals for chemical and sensory analyses. Chemical analysis was done for 4 weeks whereas sensory analysis was done for either 2 or 3 weeks depending on the development of off-flavours in the samples. **Fig. 1** provides a visual picture of various products prepared and packaging containers used for the study.

Chemical analysis

The prepared products were analyzed for moisture, fat, free fatty acids and peroxide value on the day of preparation by standard procedures. Moisture was analyzed by oven drying method (AOAC 2000). Fat was estimated by repeated extraction of samples with petroleum ether in a Soxhlet apparatus (AOAC 2000). Oil from fried products was extracted and analyzed for FFA and PV initially and on every 7^{th} day up to four weeks of storage. FFA (as % oleic acid) was estimated using an alkali titration method (AOCS 2000). PV (meq kg/product) was measured by titration with 0.1 M sodium thiosulfate solution using starch as an indicator (AOCS 2000).



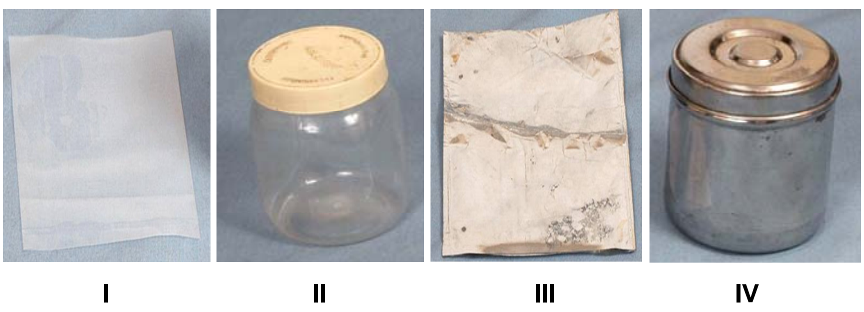


Fig. 1 Picture showing prepared products and packaging containers used for the study. Top row, Products: A: CP, B: SC, C: SMW, D: SDH, E: SET; Bottom row, Packaging containers - I: LDPE, II: PET, III: MF, IV: steel.

Sensory analysis

The fresh and stored products were subjected to sensory analysis for the quality attributes of appearance, color, texture, flavour and overall quality by 25 semi-trained panel members using a 10-point hedonic scale for sensory parameters. Coded samples were presented to panel members with a score card with a rating scale representing quality grade description as 1-2, poor; 3-4, fair; 5-6, good; 7-8, very good and 9-10, excellent (ISI 1972). Sensory evaluation was repeated every week for stored products for either 2 or 3 weeks depending upon detection of off flavour.

Statistical analysis

Data were analyzed statistically using analysis of variance to determine the level of significant differences in the sensory quality of products.

RESULTS AND DISCUSSION

Initial analysis of samples

On the day of preparation, samples were analyzed for moisture, fat and sensory attributes and results are compiled in **Table 1**. The moisture content of products ranged between 1.63-2.89%. This was expected because these were fried products with low moisture ranges and a longer shelf life. The fat content of samples showed a wide variation depending upon the ingredients and treatment. Higher fat uptake of 29.3% was observed in control product prepared only with wheat flour. Incorporation of soy flour reduced oil uptake to 20.7%, which is a considerable reduction. However, the extent of this reduction decreased when soy flour was subjected to any one of the pre-treatments. The products prepared with dry heat-treated and enzyme hydrolysed soy flour absorbed less oil in comparison with control product but more oil than soy control. The microwave product was nearer to the soy control. A reduction in fat uptake of products on incorporation of soy flour has also been observed by other researchers (Kinsella 1979). However, this property was reduced on pre-treating the flour. This can be attributed to unfolding and breakage of polypeptide chains due to denaturation and hydrolysis of protein on exposure to heat and enzyme. All the prepared products were subjected to sensory analysis to determine if there were any differences in sensory attributes of products on the initial day. The scores for all products ranged between 5.8and-6.9 for different attributes with no significant differences. This showed that incorporation of either untreated or pre-treated soy flour did not affect the sensory quality of products.

Effect of storage on free fatty acids of the product

The results of free fatty acid analysis for all products are presented in **Fig. 2**. The initial values or FFA for all products was very low ranging from 0.30-0.33 with the exception of SMW, which was 0.47. On storage, a gradual rise in FFA content was observed in all samples. The extent of increase was different for all samples. In the control product, it was 0.75% for sample at a low temperature and slightly higher for samples stored at room temperature. A higher value (1.01%) was observed for sample stored in LDPE. The SC product showed a maximum increase in FFA ranging from 1.13-2.00 for samples stored at room temperature. For this set of samples, the increase was evident in week 3 of storage itself. The SET product was similar to the control with the highest value of 0.90%. Under thermally treated samples microwave samples were very high in FFA content (1.01-1.62%), whereas SDH products were the lowest (0.52% and 0.61-0.93% for products stored at low temperature and room temperature respectively) amongst all. These results indicate that FFA formation was higher in products stored at room temperature in comparison with low temperature storage. Among different storage containers, steel and LDPE showed a high extent of FFA formation and among different samples, SC and SMW products were high in FFA content (1.13-1.62% for products stored at room temperature).

Effect of storage on peroxide value of the product

The peroxide value of products, presented in **Fig. 3** gives a different picture of storage ability of the product. At the end of week 4 of storage, the control product demonstrated a very high content of peroxide value in products stored at room temperature ranging from 20.84-24.13 meq/100 g of product. In contrast SC product had the lowest level (6.01-9.71%) of peroxide formation. All other sets of product prepared with pre-treated soy flour had values that were in between these two controls. Products stored at low temperature in all categories, control and experimental, were low in peroxide values but the ones stored at room temperature were higher. As observed with FFA contents, the products stored in steel and LDPE containers exhibited a higher level of rancidity as evident by higher peroxide values.

These results clearly indicate that the keeping quality of fried products as judged by FFA and peroxide formation was influenced by the composition of the products in terms of raw ingredients used, processing techniques, packaging container, temperature of storage and duration of storage.

Increase in free fatty acid content of stored product was comparable as reported by El-Sayed and Allam (2003) that during prolonged heating and in the presence of food moisture, hydrolysis of oil occurs and ester linkages are broken to yield free fatty acids resulting in an increased concentration of free fatty acids. They studied the effect of frying pre-fried frozen potatoes and fresh potatoes on quality of palm olein oil for a period of 10 and 20 hrs. The acid and peroxide value of fresh oil was found to be 0.184% and 1.330 meq/kg oil and increased on frying fresh potatoes for 10 hrs to 0.566% and 3.160 meq/kg respectively. On increasing the frying time to 20 hrs the values were 1.070% and 5.280 meq/kg respectively. Frying of pre-fried frozen potatoes resulted in still higher values of 0.868% and 4.190 meq/kg (for 10 hrs of frying) and 1.329% and 14.290 meq/kg (for 20 hrs of frying) respectively.

Marquez-Ruiz *et al.* (1999) determined peroxide value of oil extracted from potatoes fried in sunflower oil and

Table 1 Initial chemical and sensory analysis of products.

Analysis	Products					F Ratio
	CP	SC	SET	SMW	SDH	
Chemical analysis						
Moisture (%)	2.01 ± 0.10	1.98 ± 0.03	2.89 ± 0.05	1.63 ± 0.04	1.76 ± 0.02	-
Fat (%)	29.33 ± 0.30	20.70 ± 0.07	22.35 ± 0.10	26.60 ± 0.09	26.54 ± 0.04	-
Sensory attributes[a]						
Appearance	6.6 ± 1.20	6.0 ± 1.00	6.4 ± 1.47	6.2 ± 1.87	6.0 ± 0.93	0.84 ns
Colour	6.5 ± 1.00	6.3 ± 1.03	6.2 ± 1.69	6.0 ± 1.91	5.8 ± 1.06	1.45 ns
Texture	6.7 ± 1.24	6.5 ± 1.32	6.5 ± 1.68	6.1 ± 1.90	6.2 ± 1.38	0.90 ns
Flavour	6.8 ± 1.05	6.6 ± 1.55	6.6 ± 1.91	6.0 ± 1.83	6.0 ± 1.28	1.63 ns
Overall quality	6.9 ± 1.13	6.6 ± 1.21	6.8 ± 1.63	6.1 ± 1.54	6.0 ± 1.35	1.63 ns

a: values represent mean and standard deviations of sensory scores of 25 panel members.

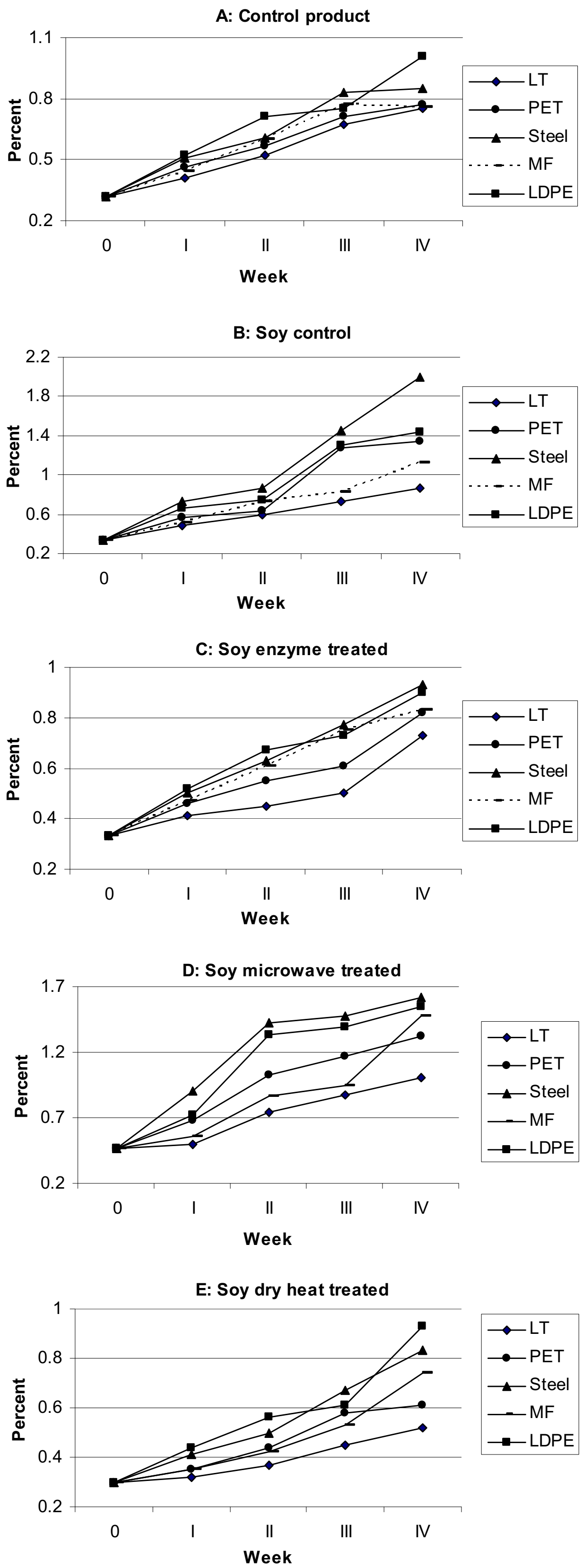


Fig. 2 Free fatty acid of extracted oil from stored products (as % oleic acid).

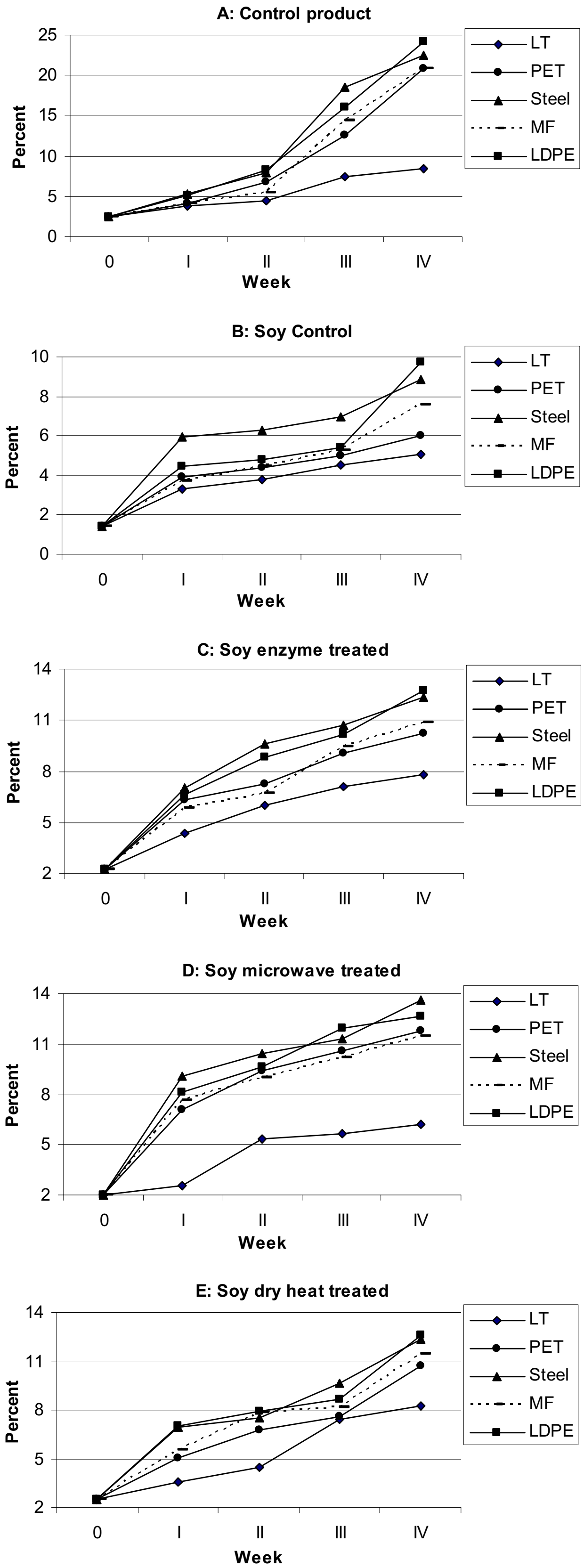


Fig. 3 Peroxide value of extracted oil from stored products (meq./kg of product).

stored at 60°C. After a storage period of 14 days, the peroxide value of extracted oil was 532 meq/kg oil in comparison to 12 of initial day. Similar value for high oleic sunflower oil was reported to be 35 meq/kg oil. This increase was attributed to accumulation of oxidized triglyceride monomers containing acyl hydroperoxides groups (Marquez-Ruiz *et al.* 1996). Romero *et al.* (1998) followed the alteration in total polar compounds of sunflower oil after repeated frying operations. These were found to be 12.3 and 20.55% after using the oil for 8 and 20 times respectively against a value of 3.7 for fresh oil. The thermooxidative and hydrolytic oxidation accounted for 87.3 and 12.3% of deterioration after 8 fryings and 91.4 and 18.6% of deterioration after 20 fryings. In a similar study done with olive oil (Romero *et al.* 2000), the total polar content of oil used for 1, 8, 12 and 20 times was 3.6, 8.1, 11.7 and

Table 2 Sensory quality of stored CP and SC products.[a]

Storage conditions	Storage duration	Appearance	Colour	Texture	Flavour	Overall quality
Control Product						
Low temperature	I week	6.4 ± 0.86	6.5 ± 0.86	6.3 ± 1.06	6.7 ± 1.22	6.7 ± 1.26
	II week	6.2 ± 1.09	6.3 ± 0.79	6.1 ± 1.09	6.2 ± 1.12	6.1 ± 0.97
	III week	6.2 ± 0.84	6.2 ± 0.89	5.9 ± 0.75	6.0 ± 0.99	6.0 ± 0.86
F- ratio		1.78 ns	1.67 ns	2.53*	5.16***	6.27***
PET	I week	6.1 ± 0.91	6.3 ± 0.85	6.2 ± 0.83	6.2 ± 0.76	5.9 ± 0.78
	II week	6.1 ± 0.88	6.2 ± 0.89	6.1 ± 1.09	5.6 ± 0.98	5.7 ± 1.10
F- ratio		1.76 ns	0.96 ns	2.21 ns	8.21***	9.57***
Metallized Foil	I week	6.2 ± 0.76	6.2 ± 0.89	6.0 ± 1.00	5.4 ± 0.95	5.2 ± 0.98
	II week	6.2 ± 0.54	6.0 ± 1.00	6.0 ± 1.09	5.4 ± 0.95	5.2 ± 0.98
F- ratio		0.70 ns	1.22 ns	3.27*	9.78***	17.13***
LDPE	I week	6.6 ± 0.95	6.5 ± 0.86	6.2 ± 1.20	5.5 ± 1.04	5.8 ± 1.01
	II week	6.1 ± 0.78	5.7 ± 0.79	5.4 ± 0.91	4.8 ± 1.08	4.9 ± 1.13
F- ratio		2.00 ns	7.04***	8.77***	22.06***	21.07***
Steel	I week	6.5 ± 0.65	6.5 ± 0.87	6.1 ± 0.80	5.3 ± 0.81	5.2 ± 1.13
	II week	6.3 ± 0.69	6.0 ± 0.57	5.6 ± 0.81	4.8 ± 1.10	4.9 ± 1.20
F- ratio		0.45 ns	2.04 ns	8.66***	24.76***	24.16***
Soy control						
Low temperature	I week	6.0 ± 1.76	6.2 ± 1.12	6.4 ± 1.29	5.7 ± 1.85	6.5 ± 1.15
	II week	6.0 ± 1.22	5.9 ± 1.13	5.2 ± 1.32	5.2 ± 1.37	5.5 ± 1.15
	III week	5.4 ± 1.35	5.4 ± 1.63	5.2 ± 1.48	5.2 ± 1.63	5.4 ± 1.32
F- ratio		2.58 ns	5.09***	7.05***	4.14***	0.27***
PET	I week	5.6 ± 1.11	5.5 ± 1.19	5.9 ± 1.65	5.8 ± 1.52	5.8 ± 1.31
	II week	5.6 ± 1.24	5.2 ± 1.33	4.7 ± 1.48	4.6 ± 1.35	4.7 ± 1.48
	III Week	5.1 ± 1.33	5.0 ± 1.36	4.4 ± 1.41	4.4 ± 1.32	4.8 ± 1.29
F- ratio		1.57 ns	5.02***	10.83***	12.50***	12.02***
Metallized Foil	I week	6.0 ± 1.01	6.1 ± 0.88	6.3 ± 1.22	6.0 ± 1.47	6.3 ± 1.03
	II week	5.9 ± 0.78	5.8 ± 1.13	5.5 ± 1.19	5.4 ± 1.41	5.5 ± 1.19
	III week	5.4 ± 1.00	5.6 ± 1.22	4.9 ± 0.93	4.9 ± 1.13	5.2 ± 0.97
F- ratio		2.07 ns	2.09 ns	9.67***	6.98***	9.02***
LDPE	I week	5.9 ± 0.75	5.8 ± 1.03	5.8 ± 1.37	5.8 ± 1.50	6.0 ± 1.29
	II week	5.7 ± 0.92	5.4 ± 1.00	5.0 ± 0.95	4.6 ± 1.58	4.6 ± 0.91
	III week	5.3 ± 1.02	5.0 ± 1.41	4.4 ± 1.00	4.4 ± 1.32	4.4 ± 1.04
F- ratio		1.97 ns	5.23***	15.58***	10.71***	23.40***
Steel	I week	6.0 ± 1.33	5.9 ± 1.27	5.6 ± 1.84	5.7 ± 1.64	5.8 ± 1.72
	II week	5.5 ± 1.35	5.3 ± 1.43	4.8 ± 1.25	4.8 ± 1.40	4.8 ± 1.40
	III week	5.0 ± 0.88	4.9 ± 1.28	4.3 ± 0.80	4.3 ± 1.22	4.3 ± 1.15
F- ratio		3.39*	6.17***	11.45***	5.08***	10.36***

a: values represent mean and standard deviations of sensory scores of 25 panel members.

Table 3 Sensory quality of stored SEM products.[a]

Storage conditions	Storage duration	Appearance	Colour	Texture	Flavour	Overall quality
Low temperature	I week	5.6 ± 0.86	5.6 ± 1.55	5.4 ± 0.75	5.8 ± 1.14	5.7 ± 0.92
	II week	5.6 ± 1.22	5.4 ± 1.26	5.3 ± 1.24	5.5 ± 1.22	5.6 ± 1.31
	III week	5.5 ± 1.19	5.4 ± 0.81	5.2 ± 1.29	5.3 ± 1.46	5.2 ± 0.83
F- ratio		1.51 ns	0.88 ns	3.13**	2.09 ns	1.85 ns
PET	I week	5.5 ± 0.87	5.4 ± 0.82	5.6 ± 0.86	5.6 ± 0.91	5.5 ± 0.91
	II week	5.4 ± 1.29	5.4 ± 1.38	5.5 ± 1.19	5.1 ± 1.21	4.9 ± 1.17
	III week	5.1 ± 1.21	5.1 ± 0.94	4.6 ± 0.69	4.8 ± 1.26	4.6 ± 1.31
F- ratio		2.84*	1.68 ns	8.55***	4.94**	6.26***
Metallized Foil	I week	5.4 ± 1.29	5.5 ± 1.12	5.2 ± 1.12	5.4 ± 1.00	5.4 ± 1.00
	II week	5.1 ± 0.92	5.1 ± 0.83	5.0 ± 0.81	5.4 ± 1.08	5.3 ± 0.94
	III week	5.1 ± 0.80	5.0 ± 1.03	4.6 ± 1.32	4.7 ± 1.61	4.4 ± 1.60
F- ratio		1.45**	3.10*	8.04***	4.51**	6.43***
LDPE	I week	5.4 ± 0.86	5.3 ± 1.24	5.6 ± 1.03	5.4 ± 0.96	5.3 ± 1.35
	II week	5.4 ± 0.91	5.2 ± 0.72	5.3 ± 1.14	5.1 ± 1.09	5.0 ± 1.15
	III week	4.9 ± 1.01	4.9 ± 1.09	4.7 ± 0.77	4.8 ± 1.02	4.7 ± 1.06
F- ratio		5.61***	3.05*	7.51***	5.88***	5.52***
Steel	I week	5.4 ± 0.70	5.4 ± 0.75	5.5 ± 0.96	5.2 ± 1.06	5.4 ± 0.95
	II week	5.4 ± 0.81	5.2 ± 1.17	5.2 ± 1.20	4.8 ± 1.08	4.8 ± 1.22
	III week	5.2 ± 0.76	4.9 ± 0.84	5.2 ± 1.05	4.6 ± 1.15	4.4 ± 1.22
F- ratio		5.10**	3.48*	3.65***	8.20***	8.52***

a: values represent mean and standard deviations of sensory scores of 25 panel members.

17.3 respectively. Of these values, 1.3, 5.7, 9.4 and 14.8 were due to thermooxidation and 2.3, 2.3, 2.4 and 2.5 were due to hydrolytic alterations in oil respectively. Romero *et al*. (1995) also reported an increase in total polar content of high oleic sunflower oil on repeated fryings (70 times) from 3.6 to 9.2% and an increase in FFA from 0.37 to 0.42%.

Sensory evaluation

The results of sensory analysis conducted for product throughout the storage period are presented in **Tables 2-4**. **Table 2** presents the sensory scores of control product made with wheat flour and by incorporating untreated soy flour. The products made with wheat flour did not have a very good keeping quality and the products stored at room

Table 4 Sensory quality of stored SMW and SDH products.[a]

Storage conditions	Storage duration	Appearance	Colour	Texture	Flavour	Overall quality
SMW Product						
Low temperature	I week	6.3 ± 0.69	6.0 ± 0.86	6.4 ± 0.86	6.6 ± 0.91	6.3 ± 0.85
	II week	6.0 ± 0.90	6.0 ± 1.15	5.8 ± 0.80	5.9 ± 1.03	5.7 ± 0.83
	III week	5.9 ± 1.06	6.2 ± 1.05	5.7 ± 1.24	5.5 ± 1.38	5.4 ± 1.08
F- ratio		2.59*	2.34 ns	5.16***	5.69***	7.98***
PET	I week	6.0 ± 0.84	5.9 ± 1.06	5.6 ± 1.14	5.7 ± 1.26	5.8 ± 1.01
	II week	5.6 ± 0.90	5.5 ± 1.26	5.1 ± 1.09	4.6 ± 1.32	5.2 ± 1.15
	III week	5.3 ± 1.35	5.4 ± 1.44	5.0 ± 1.44	4.1 ± 1.16	4.4 ± 1.15
F- ratio		4.30**	2.15 ns	6.83***	18.03***	15.82***
Metallized Foil	I week	5.8 ± 0.66	5.8 ± 0.97	6.2 ± 1.10	6.0 ± 1.22	6.1 ± 1.28
	II week	5.9 ± 1.11	5.7 ± 1.36	5.6 ± 1.32	5.2 ± 1.63	5.1 ± 1.46
	III week	5.3 ± 1.46	5.2 ± 1.45	5.0 ± 1.11	4.7 ± 1.39	5.0 ± 1.35
F- ratio		3.39*	2.17 ns	6.35***	7.16***	8.77***
LDPE	I week	5.5 ± 0.96	5.5 ± 0.96	5.3 ± 1.40	5.0 ± 1.55	5.4 ± 1.26
	II week	5.5 ± 1.08	5.4 ± 1.32	4.7 ± 1.54	4.5 ± 1.41	4.7 ± 1.30
	III week	5.4 ± 1.19	5.3 ± 1.55	4.7 ± 1.40	3.7 ± 1.06	3.9 ± 1.25
F- ratio		4.44**	2.31 ns	8.22***	19.10***	19.82***
Steel	I week	5.6 ± 1.19	5.4 ± 1.08	5.4 ± 0.91	5.6 ± 1.18	5.2 ± 1.05
	II week	5.5 ± 1.29	5.3 ± 1.31	5.0 ± 1.02	4.2 ± 1.45	4.6 ± 1.04
	III week	5.5 ± 0.82	5.2 ± 1.26	4.8 ± 1.41	3.8 ± 1.46	4.3 ± 1.49
F- ratio		3.58*	2.57 ns	9.04***	20.59***	17.36***
Soy dry heat product						
Low temperature	I week	6.1 ± 1.06	5.7 ± 1.40	5.8 ± 1.04	5.9 ± 1.06	5.8 ± 1.44
	II week	5.9 ± 0.95	5.7 ± 0.87	5.7 ± 1.10	5.7 ± 1.28	5.6 ± 1.35
	III week	5.7 ± 1.06	5.9 ± 1.39	5.5 ± 1.15	5.3 ± 1.44	5.4 ± 1.29
F- ratio		0.94 ns	0.20 ns	1.34 ns	1.20 ns	1.93 ns
PET	I week	5.8 ± 0.92	6.0 ± 0.90	5.7 ± 1.09	5.8 ± 1.73	6.1 ± 1.33
	II week	5.8 ± 1.16	5.8 ± 1.09	5.4 ± 1.35	5.2 ± 1.80	5.4 ± 1.35
	III week	5.3 ± 1.17	5.5 ± 1.40	4.9 ± 1.06	4.9 ± 1.74	5.2 ± 1.80
F- ratio		2.08 ns	0.72 ns	3.12*	2.01 ns	3.17*
Metallized Foil	I week	5.8 ± 1.31	5.6 ± 1.44	5.7 ± 1.45	5.7 ± 1.80	5.8 ± 1.50
	II week	5.8 ± 1.09	5.3 ± 1.24	5.2 ± 1.70	5.2 ± 1.55	5.2 ± 1.42
	III week	5.4 ± 1.29	5.3 ± 1.35	5.0 ± 1.39	4.9 ± 1.74	5.2 ± 1.26
F- ratio		1.20 ns	1.08 ns	2.30 ns	2.04 ns	2.48 ns
LDPE	I week	5.7 ± 0.89	5.4 ± 1.04	5.5 ± 1.26	5.6 ± 1.41	5.9 ± 1.15
	II week	5.4 ± 1.22	5.4 ± 1.22	5.0 ± 1.32	4.8 ± 1.46	5.2 ± 1.22
F- ratio		1.74 ns	1.22 ns	2.93 ns	3.68*	3.59*
Steel	I week	5.8 ± 1.38	5.7 ± 1.42	5.9 ± 1.41	6.0 ± 1.66	6.2 ± 1.61
	II week	5.8 ± 1.55	5.7 ± 1.25	5.5 ± 1.80	5.5 ± 1.66	5.6 ± 1.43
F- ratio		0.59 ns	0.21 ns	0.68 ns	0.89 ns	0.38 ns

a: values represent mean and standard deviations of sensory scores of 25 panel members.

temperature developed an off-flavour, hence, in these sets, sensory analysis was continued for only 2 weeks. No differences were found in the appearance and color of products stored in different containers. But the quality of texture was significantly lower in products stored in LDPE and steel containers as evident by sensory scoring. The differences in textural quality of products stored at low temperature and MF were marginal, whereas the PET container did not influence the texture. The flavour and overall quality of all products were significantly ($P<0.001$) influenced by storage. Products stored in LDPE and steel containers scored as only 'fair' on the grading scale at the end of week 2, whereas others were in the grading scale of 'good'. The soy control product could be stored in all containers up to 3 weeks. However, in all attributes, with the exception of appearance, significant differences in the quality attributes were observed. Significantly different scores were given to the quality of colour with the exception of the product stored in MF. However, as per the quality grading most of them were in the category of 'good'. The texture, flavour and overall quality were all affected significantly due to storage. The grade description of products stored at low temperature was - 'good', and for products stored in all other conditions ranged from fair to good. A definite deterioration in sensory quality of products was observed as the duration of storage increased.

The results of sensory analysis conducted for SEM products followed a different pattern when compared with control samples (**Table 3**). The scores given to products stored at a low temperature ranged from 5.2 to 5.8. Duration of storage did not influence the quality attributes of products except for texture. The products stored in PET, did score lower as the storage period increased and the differences were significant for appearance, texture, flavour and overall quality. The scores for products stored in MF, LDPE and steel ranged from 4.4–5.6 with significant differences in all categories. In comparison to sensory quality of control products, SEM products obtained lower scores indicating that enzyme pre-treatment of soy flour did not improve the sensory quality of products.

The sensory attributes of products prepared with thermally treated soy flour were marginally different in appearance but similar for the quality of colour (**Table 4**). For texture, flavour and overall quality the differences were highly significant ($P\leq0.001$). The scores obtained after week 1 of storage were higher but after week 2 they were remarkably lower in LDPE and steel containers confirming the quality description of 'fair'. In products prepared with dry heat-treated soy flour, low temperature and MF storage did not influence the sensory quality for any of the attributes tested. In products stored in PET containers, texture and overall quality were marginally ($P\leq0.05$) affected. The products stored in LDPE and steel developed off-flavor, hence the evaluation was conducted only for 2 weeks. There were no differences in products stored in steel containers, but in LDPE stored products, flavour and overall quality were slightly affected.

The overall analysis of sensory results indicated that the incorporation of soy flour improved the keeping quality of products. Pre-treatment of soy flour with enzyme trypsin lowered the quality of the product, but thermal treatment improved sensory scores. Among storage conditions, low temperature, PET and MF were better. Organoleptically, the products were acceptable up to 2 weeks; however, the sensory quality deteriorated thereafter indicating an optimum storage time of 2 weeks.

Consumption of soy has been associated with many health benefits and many processed foods incorporate soy in different forms such as defatted flour, protein concentrates, protein isolates, hydrolysed proteins, textured soy products etc. It can be concluded from the results of present study that incorporation of soy reduced oil uptake in deep fried wheat-based products. Hence, this finding can be used to lower the fat content in fried products by incorporating soy. It was also observed that deterioration of oil in stored soy incorporated products was comparatively less indicating that soy improves the keeping quality of products. Incorporation of soy had no adverse effect on the sensory quality of products. All products stored at low temperature were acceptable for three weeks. The CP stored in different packaging material and SDH product stored in LDPE and steel containers at room temperature were acceptable only up to 2 weeks. Incorporation of soy can be recommended for wheat-based fried snack products for lower oil uptake, better keeping and sensory quality.

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