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ORIGINAL ARTICLE

Influence of storage and packaging conditions on the quality of soy flour from sprouted soybean

Dipika Agrahar-Murugkar · Krishna Jha

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Abstract Full fat soy (*Glycine max* L) flour (FFSF) from germinated 'MAUS 47' variety was packed in Al foil laminated paper (75 microns Al foil), low density polyethylene (LDPE, 125 microns), biaxially oriented polypropylene (BOPP, 100 microns) packets and polyethylene tetraphthalate (PET) jars and stored in ambient (25–35 °C, 45–55%RH) and accelerated conditions (40 °C, 90% RH) and tested every 15 days for a period of 75 days for changes in moisture, protein, fat, free fatty acid and nitrogen solubility. Increase in contents of moisture and free fatty acid with corresponding decrease in fat and solubility were observed in all stored packs more under accelerated conditions as compared to ambient conditions of storage. Among packaging materials FFSF from sprouted soybean was best kept in Al foil laminated packages followed by LDPE and BOPP packaging materials. Flour from sprouted soybean could be kept safely for 90 days in ambient and 75 days in accelerated conditions.

Keywords Soybean · Germination · Packaging · Shelf life

Introduction

Full fat soy flour, a promising soy product is gaining popularity in India as it is easily incorporated into traditional Indian recipes and fits well into local dietary patterns (Sushma et al. 1979). However the development of off-flavour during processing and storage seriously limits its full utilisation. Apart from enzymatic deterioration due to lipoxygenase, non-enzymic decomposition of lipid peroxides is also a problem (Gardner 1975).

Germination processes have been developed to overcome some of the disadvantages associated with undesirable flavour and odour (McKinney et al. 1958; Suberbie et al. 1981; Van der Stoep 1981). Lipoxygenase I, II and III are degraded during germination preventing formation of volatile compounds (Vineet Kumar et al. 2006) and the substantial odour and flavour scores of germinated soybean are improved. Akubor and Obiegbuna (1999) have reported a significant decrease in fat on germination. The decreasing pattern in free fatty acid during germination is probably due to the greater rate of metabolism of fatty acids relative to their liberation (McKinney et al. 1958), which may increase shelf–life of the flour. Due to decreased content of fat, fatty acid and increased solubility of soyflour made from sprouted soybeans (Agrahar-Murugkar and Jha 2009) and it might have a longer shelf life compared to its unsprouted counter part. Shelf life is also influenced by several factors such as exposure to light and heat, transmission of gases (including humidity), mechanical stresses and contamination by things such as microorganisms.

Therefore the present study was conducted to assess the effect of packaging materials (LDPE, BOPP, Al foil laminated pouches and PET jars) and time under ambient and accelerated storage on stability of FFSF from sprouted soybean.

Materials and methods

'MAUS 47' variety of soybean (*Glycine max* L) was harvested in November 2006, procured from Marathwada Agricultural University, Parbhani, Mahahrashtra and stored at 20 °C and 30% RH for further studies. Soybean seeds

D. Agrahar-Murugkar (✉) · K. Jha
Agro Produce Processing Division,
Central Institute of Agricultural Engineering,
Nabibagh, Berasia road,
Bhopal 462038, India
e-mail: dipikaagrahar@yahoo.com

were cleaned thoroughly and made free from dust, dirt, stubbles and foreign matter. Damaged seeds with cracked hull etc. were discarded and the seeds were surface sterilized with 0.1% (w/v) potassium permanganate solution. They were then rinsed with distilled water to remove any traces of potassium permanganate. About 20 g of seeds were soaked in 60 ml distilled water for 4 h. Then, the excess water was drained, sample further rinsed with distilled water, seeds placed in a single layer on filter paper in sterile petridishes and placed in the Seed Germinator (Indosaw India) at the 25 °C, 90% RH for 72 h. as per the method of Agrahar-Murugkar and Jha (2009). The sprouted samples (seeds and cotyledons) were weighed and dried in oven at 60 °C till constant weight. The sample was milled and sieved (Sieve number IS 30) to obtain a fine powder. This powder was sealed and stored in different packaging materials LDPE 125 microns, BOPP 100 microns, Al foil 75 microns laminated with paper, (PET containers and open packs as control) and kept under ambient conditions (25–35 °C,45–55% RH) and accelerated conditions (40 °C, 90% RH) until further use for analysis. The samples were analysed every 15 days up to 75 days (90 days for free fatty acids). The moisture content, crude protein and fat contents of the samples were estimated by AOAC (1995) methods. The free fatty acid% was determined by AOCS (1989) method and nitrogen solubility index (NSI) by the method of Daun and DeClercq (1994).

The experiment was conducted in triplicate and the average values were computed. The data was statistically analysed using statistical packages of SYSSTAT 7.0 for windows.

Results and discussion

Results are presented in Table 1.

There was a significant ($p<0.5$) increase in moisture content in all the samples during storage. The rate of increase was more significant under accelerated conditions of storage and also varied depending on packaging material. The moisture increase in open samples was most dramatic and increased from 5.4% at 0 days to 14.4% (ambient conditions) and 15.5% (accelerated conditions) after 75 days. The moisture content should be below 9% as per Indian standards (IS: 7836 AND 7837 1975). Accordingly, open samples can be kept for less than a month under ambient conditions and for less than 15 days under accelerated conditions. In samples packed in PET jars, flour can be kept for 30 days (ambient) and 15 days (accelerated), in LDPE and BoPP packages for 45 days (ambient) and 30 days (accelerated) and in Al foil laminated packages for 60 days (ambient) and 45 days (accelerated). The variation in moisture contents of these products could be directly related to the water vapour transmission rate of the packaging materials. The laminated packages were most effective and least moisture could migrate through them. This was mainly due to the fact that aluminum foil is considered to have a very low water vapour transmission rate (WVTR) under humid condition (80%RH) (Bargale et al. 1993). Another reason could be due to the role of microorganisms, which utilized the soy carbohydrates as the source of energy, soy-protein as the source of nitrogen and ultimately hydrolyzing the lipids and releasing water indicating increase in moisture content. Insects that live on stored grains and their products depend upon the moisture supply. Generally, moisture content of 9% or lower restricts infestation. Moisture is also of great importance for the safe storage of cereals and their products regarding microorganisms, particularly certain species of fungi. At lower moisture fungi will not grow but at about 14% or slightly above, fungal growth takes place (Hoseney 1994). The deterioration of baking quality is also less at lower moisture content which can be created to retard respiration and activity of microorganisms (Staudt and Ziegler 1973). Higher lipolytic and proteolytic activities are related to higher moisture content, which further lead to loss in nutrients (protein and fat) and production of more FFA resulting in inferior sensory characteristics. The moisture content is affected significantly due to storage, treatments, packaging, and their interaction and moisture increases throughout the storage period and is caused by changes due to the hygroscopic properties of flour (Kirk and Sawyer 1991; Rehman and Shah 1999).

A marginal drop in protein contents was seen after 15 days after with slight increases in the protein content was seen with time. Similar results have been observed by other workers where the crude protein of the samples having higher moisture levels increased due to insect infestation and microbial growth (Leelavathi et al. 1984; Upadhyay et al. 1994).

There was a progressive decrease in the fat contents of the samples with time more under accelerated conditions than ambient conditions. The highest decrease in fat was seen in open samples where levels fell from 18.7% at 0 days to 17.4% (ambient) and 17.2% (accelerated) after 75 days followed by the flour stored in PET jars (18.0%-ambient and 17.8%- accelerated) after 75 days. Reductions in fat contents were much lesser in flour packed in LDPE packages (18.0% ambient, 17.9% accelerated) and BoPP (18.2%- ambient and 18.1%- accelerated). The lowest drop in fat level was in flour packed in Al-foil packages (18.3% ambient and 18.2% accelerated). The decrease may be attributed to the lipolytic activity of enzymes i.e. lipase and lipoxidase.

The FFA values of the flour showed a gradual ($p<0.5$) increase with time. All samples had FFA values below 0.9% till 1 month after which depending on the packaging material, the levels increased above the permissible limit

Table 1 Effect of packaging and storage on quality characteristics of sprouted full fat soy flour

Storage period, day	Open		LDPE (125 microns)		BOPP (100 microns)		Al–foil (2 mm)		PET jar	
	Am*	Ac*	Am*	Ac*	Am*	Ac*	Am*	Ac*	Am*	Ac*
Moisture% (Initial value-IV 5.4)										
15**	$8.3^{d}\pm0.03$	$9.9^{e}\pm0.07$	$6.0^{b}\pm0.01$	$6.7^{b}\pm0.07$	$6.5^{b}\pm0.92$	$6.7^{b}\pm0.52$	$5.5^{a}\pm0.62$	$5.5^{a}\pm0.58$	$6.5^{b}\pm0.47$	$7.3^{c}\pm1.01$
30**	$9.5^{c}\pm0.02$	$10.9^{d}\pm0.04$	$7.7^{ab}\pm0.01$	$8.8^{b}\pm0.66$	$6.6^{a}\pm1.01$	$7.0^{a}\pm0.66$	$6.7^{a}\pm0.35$	$7.0^{a}\pm0.46$	$7.7^{ab}\pm0.52$	$8.1^{b}\pm0.99$
45**	$10.6^{c}\pm0.05$	$11.5^{d}\pm0.02$	$8.0^{a}\pm0.05$	$9.9^{b}\pm0.52$	$7.7^{a}\pm0.15$	$8.8^{ab}\pm0.71$	$7.7^{a}\pm0.59$	$7.8^{a}\pm0.91$	$8.7^{ab}\pm0.69$	$9.5^{b}\pm0.84$
60**	$12.5^{c}\pm0.06$	$14.2^{d}\pm0.05$	$9.7^{ab}\pm0.04$	$11.0^{bc}\pm0.49$	$8.9^{a}\pm0.26$	$9.4^{a}\pm0.53$	$8.8^{a}\pm0.66$	$9.1^{a}\pm0.83$	$9.9^{ab}\pm0.18$	$10.3^{b}\pm0.74$
75**	$14.0^{d}\pm0.05$	$15.5^{e}\pm0.04$	$11.1^{b}\pm0.03$	$13.7^{c}\pm0.66$	$9.0^{a}\pm2.33$	$10.9^{b}\pm1.22$	$9.0^{a}\pm0.15$	$10.6^{b}\pm0.77$	$11.1^{b}\pm0.29$	$13.6^{c}\pm0.69$
Protein%, (IV-41.5)										
15	39.5±0.12	39.5±1.03	41.5±1.33	39.8±1.71	41.4±1.51	40.0±1.83	42.0±1.23	40.6±1.52	40.1±1.24	40.5±1.88
30	40.8±0.17	40.8±1.18	40.8±1.26	41.0±1.23	41.0±1.29	40.4±1.53	40.6±1.48	41.0±1.17	41.3±1.57	39.7±1.39
45	41.4 ±0.65	41.3±1.32	41.6±1.41	41.8±1.05	40.9±1.70	42.0±1.99	41.6±1.65	40.5±1.92	41.7±1.63	41.1±1.45
60	41.4±0.73	41.4±1.04	41.2±1.25	42.0±1.40	41.6±1.66	40.3±1.68	41.1±1.53	41.8±1.68	41.2±1.82	41.8±1.26
75	41.8±0.66	41.4±1.29	41.4±1.33	41.4±1.11	40.3±1.92	40.4±1.33	41.9±1.92	41.6±1.73	41.5±1.77	41.0±1.33
Fat%, (IV-18.7)										
15	18.7±1.15	18.5±1.00	18.7±1.02	18.7±1.63	18.7±1.13	18.7±1.02	18.7±1.33	18.7±1.64	18.7±1.56	18.7±1.01
30	18.4±1.11	18.3±1.06	18.6±0.88	18.5±1.15	18.7±1.03	18.6±0.97	18.7±1.47	18.7±1.39	18.7±1.38	18.4±1.03
45	18.0±1.32	17.5±1.90	18.4±0.65	18.4±1.90	18. 6±1.99	18.5±1.36	18.7±1.52	18.6±1.45	18.3±1.49	18.1±1.08
60	17.7±1.44	17.3±1.63	18.3±1.16	18.4±1.09	18.5±1.06	18.4±1.71	18.5±1.33	18.2±1.28	18.0±1.51	17.9±1.06
75	17.5±1.24	17.2±1.22	18.0±1.33	18.0±1.77	18.2±1.55	18.1±1.05	18.3±1.49	18.2±1.58	18.0±1.81	17.8±1.10
Free Fatty acid%, (IV-0.41)										
15**	$0.59^{bc}\pm0.01$	$0.67^{c}\pm0.03$	$0.45^{a}\pm0.12$	$0.53^{b}\pm0.09$	$0.41^{a}\pm0.05$	$0.52^{b}\pm0.02$	$0.42^{a}\pm0.05$	$0.50^{b}\pm0.04$	$0.53^{b}\pm0.05$	$0.59^{bc}\pm0.02$
30**	$0.75^{d}\pm0.02$	$0.84^{e}\pm0.08$	$0.44^{a}\pm0.05$	$0.56^{b}\pm0.08$	$0.42^{a}\pm0.06$	$0.58^{b}\pm0.06$	$0.45^{a}\pm0.01$	$0.55^{b}\pm0.02$	$0.64^{c}\pm0.04$	$0.75^{d}\pm0.03$
45**	$0.95^{d}\pm0.06$	$0.96^{d}\pm0.01$	$0.45^{a}\pm0.03$	$0.64^{b}\pm0.06$	$0.47^{a}\pm0.07$	$0.65^{b}\pm0.08$	$0.42^{a}\pm0.06$	$0.65^{b}\pm0.08$	$0.76^{c}\pm0.62$	$0.92^{d}\pm0.05$
60**	$0.98^{c}\pm0.03$	$1.39^{e}\pm0.07$	$0.51^{a}\pm0.02$	$0.75^{b}\pm0.09$	$0.52^{a}\pm0.03$	$0.77^{b}\pm0.08$	$0.50^{a}\pm0.07$	$0.74^{b}\pm0.06$	$0.93^{c}\pm0.28$	$1.12^{d}\pm0.03$
75**	$1.35^{c}\pm0.02$	$1.5^{d}\pm0.05$	$0.84^{a}\pm0.06$	$0.90^{a}\pm0.06$	$0.85^{a}\pm0.06$	$0.90^{a}\pm0.03$	$0.82^{a}\pm0.09$	$0.85^{a}\pm0.05$	$1.28^{b}\pm0.39$	$1.47^{d}\pm0.08$
90**	$1.45^{c}\pm0.03$	$1.7^{e}\pm0.08$	$0.91^{a}\pm0.07$	$1.4^{c}\pm0.07$	$0.92^{a}\pm0.05$	$1.12^{b}\pm0.06$	$0.9^{a}\pm0.08$	$1.1^{b}\pm0.06$	$1.32^{c}\pm0.14$	$1.56^{d}\pm0.07$
NSI%,(IV-77.0)										
15**	$61.7^{ab}\pm1.12$	$61.5^{ab}\pm1.23$	$68.9^{b}\pm1.16$	$63.0^{b}\pm1.95$	$70.3^{c}\pm1.66$	$59.1^{a}\pm1.23$	$72.5^{c}\pm1.48$	66.8±1.25	$61.0^{ab}\pm1.54$	$57.6^{a}\pm1.26$
30**	$61.2^{b}\pm1.06$	$51.6^{a}\pm1.56$	$63.0^{b}\pm1.89$	$58.2^{ab}\pm1.99$	$62.2^{b}\pm1.28$	$57.2^{a}\pm1.40$	$71.2^{c}\pm1.56$	$60.0^{ab}\pm1.36$	$61.1^{b}\pm1.69$	$50.9^{a}\pm1.36$
45**	$51.7^{a}\pm1.35$	$50.6^{a}\pm1.99$	$59.4^{c}\pm1.15$	$56.2^{bc}\pm1.92$	$58.9^{c}\pm1.33$	$53.5^{b}\pm1.60$	$70.6^{d}\pm1.28$	$58.6^{c}\pm1.71$	$55.3^{b}\pm1.55$	$49.0^{a}\pm1.34$
60**	$45.5^{a}\pm1.46$	$42.3^{a}\pm1.36$	$55.7^{bc}\pm1.14$	$54.1^{b}\pm1.82$	$58.3^{c}\pm1.92$	$52.3^{b}\pm1.09$	$66.6^{d}\pm1.37$	$58.0^{c}\pm1.69$	$49.1^{ab}\pm1.36$	$47.4^{ab}\pm1.45$
75**	$40.6^{a}\pm1.23$	$39.7^{a}\pm1.33$	$50.8^{c}\pm1.66$	$48.4^{bc}\pm1.74$	$60.7^{d}\pm1.46$	$50.5^{c}\pm1.07$	$66.5^{e}\pm1.11$	$57.5^{cd}\pm1.59$	$43.8^{b}\pm1.72$	$41.1^{a}\pm1.55$

Am-Ambient condition (25–35 °C, 45–55% RH), Ac- Accelerated condition (40 °C, 90% RH) (n=3)

* Significant between Ambient and Accelerated condition $P<0.5$, ** Significant between time periods $P<0.5$

Means having different superscripts are significantly different between columns ($p<0.05$)

(IS 7837: 1975). In open packs, samples under ambient had safe limits for 45 days while under accelerated conditions it was safe for around 30 days. In PET jars samples were safe between 45 and 60 days in ambient and 45 days in accelerated conditions. Flour remained safe in BOPP and LDPE packages for 60 days in accelerated and 75 days under ambient conditions. The flour in Al laminated packages were safe for 75 days in accelerated and between 75 and 90 days in ambient conditions. Mustakas et al. (1969) have also reported fatty acid levels of 0.99% after 60 days on storage in LDPE bags. Generally, an increase in FFA values was more influenced by the storage temperature than humidity .The Al-laminated packages proved to be more effective for checking the FFA increase than the LDPE packages (Haridas et al. 1983; Leelavathi et al. 1984) as also observed in our study

Nitrogen solubility index (NSI) is considered to be indicative of available nitrogen. A higher value of NSI is always desired but as results indicated, it had a decreasing ($p<0.5$) trend during storage as well as significant differences between packaging materials. The greatest decrease in NSI was seen in open samples under accelerated conditions after 75 days. The levels of NSI in flour packed in LDPE were 50.8 (ambient) and 48.4 (accelerated); BOPP was 60.7 (ambient) and 50.46 (accelerated); PET was 43.8 (ambient) and 41.1 (accelerated) after 75 days. Al foil laminated packages had the highest levels of NSI after 75 days at 66.5 under ambient and 57.5 under accelerated conditions. The fall in NSI can be attributed to the exposure of the flour to atmospheric moisture, which again depends on the gas and water vapour transmission rate, increased oxygen availability and comparatively easy internal contamination of flour by airborne microorganisms. Other studies also show similar results where the solubility decreased more in LDPE packs as compared to Al foil laminated packaging of soya flakes due to differences in gas and water vapour transmission rate (Bargale et al. 1993).

Conclusion

The FFSF from sprouted soybean can be best kept in Al foil laminated packages followed by LDPE and BOPP packaging materials. The FFSF from sprouted soybean could be kept safely for 90 days in ambient and 75 days in accelerated conditions.

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