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QUALITY AND SHELF-LIFE EVALUATION OF MULTIGRAIN GLUTEN FREE BISCUITS DEVELOPED FROM SORGHUM, SOYBEAN AND OAT COMPOSITE FLOURS BLEND

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ABSTRACT

The present study examined the effects of sorghum, soybean, and oat flour as multigrain ingredients in biscuits on baking, textural, and sensory qualities and shelf life of multigrain gluten-free (MGF) biscuits. The MGF biscuits were made using soybean flour (0, 10, 20, 30%), oat flour (0, 5, 10, 15%), and sorghum flour (85, 70, 55%). MGF biscuits with 65% sorghum, 15% oat, and 20% soybean flour spread well. Its colour, appear, top grain, flavour, taste, and general acceptability impressed the sensory panel. Thus, biscuits with 65% sorghum flour, 15% oat flour, and 20% soybean flour were chosen for storage trials. The biscuits have 2.87 % moisture, 1.65 % ash, 11.69 % crude protein, 28.56 % fat, 2.57 % crude fibre, and 55.47 % carbs. During storage, 65 percent sorghum flour, 15 percent oat flour, and 20 percent soybean flour biscuits were tested for moisture, water activity, hardness, colour, and sensory quality in polypropylene (PP) and aluminum laminates (AL). Both PP and AL packaging materials reduced MGF biscuit moisture. The water activity of biscuits made with 100% sorghum flour was higher than that of biscuits made with 65% sorghum flour, 15% oat flour, and 20% soybean flour. 100% sorghum flour biscuits increased water activity more than MGF biscuits during storage. Storage made MGF biscuits harder. 100% sorghum biscuits toughened more than MGF. Biscuits made with 65% sorghum flour, 15% oat flour, and 20% soybean flour did not expand after 60 days, although their taste changed. MGF biscuits provide 11.69% protein and 2.57% fibre. Biscuits in polypropylene and aluminum laminates can be stored for 60 days at 30±1°C.

***Key words*:** Biscuits, Gluten, Multigrain, Sorghum flour, Soybean, Shelf-life.

Introductions

There has been a remarkable shift in customer expectations and demands within the food manufacturing industry in the past several years. Modern food isn't just supposed to fill people up and provide them with nutrients; it's also meant to prevent diseases linked to poor nutrition. Baked goods centered around composite flour, such as crackers, nibbles, and biscuits, have recently seen a surge in demand from health-conscious consumers. The majority of people throughout the world eat baked goods on a regular basis, and for good reason: they're an excellent source of dietary fibre and antioxidant components. Therefore, it is essential to fortify bread goods with components that are rich in fibre. Even if consuming a particular formulation is not strictly necessary for human survival, functional foods have been shown to have a distinct health benefit beyond their nutritional value. Bakery items and other multigrain preparations often include wheat flour, other cereal grains, and sometimes even oil seeds in their preparation. The most common cereals included in multigrain baked goods to improve structure, flavour, texture, nutritional diversity, and customer acceptance are oats, corn, soy, barley, rye, rice, amaranth, triticale, and buckwheat. Cereal grains are an important source of carbs, protein, fibre, minerals, and vitamin B. A growing number of age-related disorders

may be preventable with the help of multigrain products, which are attracting the attention of a health-conscious public.

The three primary components of the sorghum kernel the seed or fruit coat (7.9%), the embryo or germ (9.8 %), and the endosperm (82.3 %)make up the approximately spherical kernel. Sorghum contains 11.9 % water, 10.4 percent protein, 1.9 % fat, 72.6 % carbs, 1.6 % crude fibre, and 1.6 % minerals in its chemical makeup. Celiac disease (CD), an autoimmune reaction to gluten, is becoming more common; sorghum is a gluten-free cereal that can help such people.

Although oats (*Avena sativa* L.) aren't as widely eaten as wheat and rice, they contain an abundance of chemicals with antioxidant properties, including phenolic compounds, phytic acid, vitamin E (tocopherols), avenanthramides, flavonoids, and sterols. Approximately 60% of oats are carbohydrate, 14% are protein, 7% are lipids, and 4% are β-glucan. Oats are unique among grain crops since they contain a lot of protein and fats. Oats are unique because they contain a lot of dietary fibre, particularly soluble β-glucans. Oats are an excellent source of potassium, one of the micronutrients. Oats also include other, less significant components, like phenolics. By weight, dehulled soy flour had 10.4% moisture, 49.3% protein, 25.9% fat, 2.8% ash, 3.0% fibre, and 18.6% total carbohydrates.

Altindag *et al.*, (2015) tested the impact of transglutaminase (TG) on the quality of gluten-free cookies made using buckwheat, rice and maize flour in varying quantities. Avila *et al.*, (2017) developed a multigrain strategy to make gluten-free cakes using cowpea, quinoa, proso millet, chickpeas, flaxseed, and white rice flour.

Biscuits were made by Cukelj *et al*., (2017) using a 10% flaxseed mixture with whole wheat, rye, oats, and barley. Mixed with 30% oat bran and 20% barley bran, whole wheat flour can be transformed into delicious biscuits. The GI ratings for oat flour vary between 53.6% and 92.0%. With the addition of extra components like raisins and dried fruits, oat mueslis or muffins have lower GI values.

A combination of sorghum, soybean, and oat flour in biscuits has not been reported. Thus, this study examined the impact of sorghum, soybean, and oat flour as multigrain ingredients in biscuits on baking, textural, and sensory qualities. Thus, this study was proposed to optimize sorghum, soybean, and oat flour amounts in biscuits, characterize them physico-chemically and sensorially, and examine their shelf life.

Materials and Methods

Location and raw materials: The work was carried out in College of Food Processing Technology and Bio Energy, Anand Agricultural University, Anand, Gujarat**.** Sugar, soybean flour, sorghum flour, oat flour, salt and other ingredients for product preparation procured from local market.

Treatment levels

Soybean flour (10, 20, 30 %), oat flour (5, 10, 15 %) and sorghum flour (85, 70, 55 %) were incorporated in MGF biscuits. MGF biscuits packed in aluminum laminates (AL) and polypropylene (PP) and stored at 30±2°C temperature condition for further storage study.

Four repetitions of the entire experiment were carried out, and single factorial and three factorials in a fully Randomized Design (CRD) were chosen for data analysis.

Analysis: Physico-chemical characteristics of biscuits were analyzed using standard procedures (AACC, 2000).

(i) **Moisture:** The standard approach outlined in 44.15 A was adhered to, as per the AACC (AACC, 2000). The sample, which weighed two grams, was dried in a desiccator after being heated to 130±1°C for one hour in a clean, dry, and pre-weighed moisture dish. The percentage of moisture loss was computed.

(ii) **Protein:** The AACC (2000) standard method outlined in 46-11 A was observed. In a Kjeldhal flask, the weighted sample was digested with a mixture of copper sulphate and potassium sulphate in a 1:10 ratio, along with concentrated H_2SO_4 (20 ml), until it turned a pale green colour. After cooling, the liquid was strained. Distillation of the digested sample with saturated NaOH (80 ml) produced ammonia, which was subsequently collected in 0.1N HCl in order to determine the percentage of nitrogen (N_2). Factoring the percentage of N_2 into the equation yielded the protein content. The computation was performed using a factor of 5.70.

(iii) **Ash:** Following the standard method outlined in 08-01, the AACC (AACC, 2000) was followed. The sample, which weighed 5 g, was scorched on a hot plate before being burned in a furnace set at 550±10°C for three hours. After cooling, the mass was measured, and the percentage of ash was reported.

Table 1: Treatment combinations.

Sr. No.	Ingredients	Control (T_0)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
1	Sorghum (g)	100	85.0	75.0	65.0	80.0	70.0	60.0	75.0	65.0	55.0
2	Oat (g)	0.0	5.0	5.0	5.0	10.0	10.0	10.0	15.0	15.0	15.0
3	Soybean (g)	0.0	10.0	20.0	30.0	10.0	20.0	30.0	10.0	20.0	30.0
4	Shortening (g)	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
5	Sugar (g)	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
6	Sodium bicarbonate (g)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
7	Ammonium bicarbonate (g)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
8	Vanilla powder (g)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
9	Salt (g)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10	SMP (g)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
11	Water/milk (ml)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
12	Essence (ml)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

(iv) Fat: The AACC (2000) standard method was adhered to in accordance with 30-10. The Soxhlet equipment was used in conjunction with petroleum ether to extract the sample, which was weighed and placed in thimbles. After the fat was extracted, the ether was retrieved and the round-bottom flask was weighed. The findings were presented as a percentage of fat.

Product preparation: With minor adjustments, the biscuits were made in accordance with conventional processes (AACC, 2000) as per the Table 1.

Weight of all the ingredients
↓
Creaming of sugar & fat
↓
Add the milk/water
↓
Add the dry ingredients in cream
↓
Dough preparation
↓
Sheeting of dough
↓
Cutting of dough by biscuit cutter
↓
Panning
↓
Baking at 180°C for 20 minutes
↓
Remove tray and cool for 30 minutes
↓
Packaging

Flow chart for biscuits making

Sensory evaluation: A panel of semi-trained judges assessed the sensory qualities of the produced product (Larmond, 1970). To measure likeness and dislikeness, a nine-point hedonic scale was utilised. The following scorecard was used to assess the cookies' sensory quality.

Proforma for sensory evaluation of cookies

Name of the panelist: date:

Name of the product: time:

Sample Code	Appea-rance	Top grain	Text-ure	Flavor	Taste	Overall accept-ability	Comment (If Any)

Scores to be given as follows:

Liked extremely – 9
Liked very much – 8
Liked moderately – 7
Liked slightly – 6
Neither liked nor disliked – 5
Disliked slightly – 4
Disliked moderately – 3
Disliked very much – 2
Disliked extremely – 1

Signature of Panelist

Shelf life: Biscuits were stored for 60 days at ambient conditions. Stored biscuits were analyzed after each 15 days interval for moisture, textural properties and sensory quality.

Observations recorded

(i) Chemical analysis: Protein, ash, moisture, and fat content were examined in biscuits.

Table 2: Effect of incorporation of sorghum, oat and soybean flour on the baking and sensory score of biscuits.

Treatment	Diameter (cm)	Thickness (cm)	Spread ratio	Appearance	Taste	Top grain	Flavor	Texture	Overall acceptability
T_0	5.00	1.18	4.26	7.03	7.19	7.03	6.82	6.90	6.99
T_1	5.13	1.14	4.52	6.79	6.94	6.90	7.00	7.13	6.95
T_2	5.13	1.04	4.95	7.15	7.07	7.10	7.30	7.42	7.21
T_3	5.19	1.03	5.03	6.65	7.24	7.03	6.94	7.32	7.04
T_4	5.31	1.05	5.09	7.60	7.53	6.76	6.99	7.48	7.27
T_5	5.08	1.01	5.05	7.30	7.44	7.25	7.49	7.30	7.36
T_6	5.22	1.05	4.96	7.05	7.40	6.65	7.25	6.95	7.08
T_7	5.23	1.04	5.05	7.09	7.05	6.75	7.15	6.75	6.96
T_8	5.29	1.01	5.25	8.06	8.05	8.06	7.88	7.90	7.99
T_9	5.25	1.08	4.87	6.98	6.80	6.30	6.30	6.05	6.49
S.Em.±	0.04	0.02	0.10	0.26	0.25	0.26	0.29	0.29	0.16
CD (0.05)	0.11	0.06	0.28	0.72	0.69	0.73	0.82	0.82	0.46
CV%	1.48	3.84	3.92	11.29	10.78	11.78	12.93	13.01	7.25

Mean of four replicates

T_0: Sorghum biscuits-100% sorghum flour;
T_1: 85% sorghum flour + 5% oat flour + 10% soybean flour;
T_2: 75% sorghum flour + 5% oat flour + 20% soybean flour;
T_3: 65% sorghum flour + 5% oat flour + 30% soybean flour;
T_4: 80% sorghum flour + 10% oat flour + 10% soybean flour;
T_5: 70 % sorghum flour + 10% oat flour + 20% soybean flour;
T_6: 60% sorghum flour + 10% oat flour + 30% soybean flour;
T_7: 75% sorghum flour + 15% oat flour + 10% soybean flour;
T_8: 65% sorghum flour + 15% oat flour + 20% soybean flour;
T_9: 55% sorghum flour + 15% oat flour + 30% soybean flour

(ii) Physical quality: Measurements of thickness, diameter, and spread ratio were taken from the biscuits. The spread ratio can be determined using this formula (AACC, 2000).

(iii) $$\text{Spread ratio} = \frac{\text{Average diameter of 6 biscuits}}{\text{Average thickness of 6 biscuits}}$$

(iv) Organoleptic quality: A team of judges used a nine-point hedonic scale to assess the biscuits' top grain, appearance, flavour, texture, and overall acceptance.

Texture analysis of biscuits (hardness): The biscuits' texture was assessed using a texture analyzer (Bourne, 1982). Hardness (N) of biscuits measured by compressing them. Distance (15 mm), force (50 kg), test speed (1 mm/s), and post-test speed (1 mm/s) were the parameters utilized for the test.

Color measurements of biscuits: According to Kimura *et al*., (1993), a spectrophotometer was used to measure the L value (100 = white; 0 = black), a value (+, red; -, green), and the b value (+, yellow; -, blue) in order to determine the crust colour. The sample holder was used to take three separate measurements of the surface colour of a biscuit.

Shelf life: There were noticeable shifts in sensory qualities, water activity, textural qualities, and moisture. Using the same methods as above, scientists checked the moisture content, water activity, and textural characteristics of the stored MGF cookies every fifteen days.

Statistical analysis: Appropriate statistical software was used to analyze the gathered data (CRD). The complete experiment was repeated four times, and results were analyzed using a completely Randomized Design (CRD) with single and three factorials.

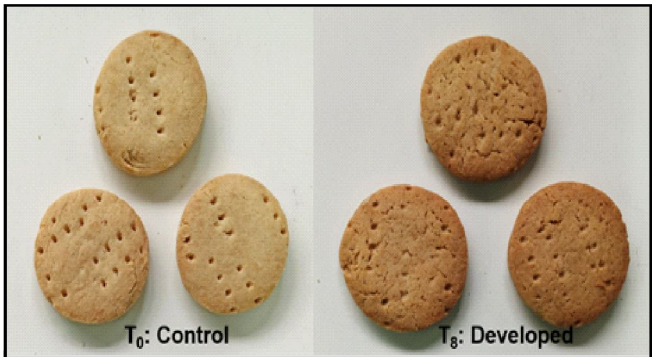
Results and Discussion

Preparation of multigrain biscuit: Biscuits were prepared by incorporating soybean flour (0, 10, 20, 30 %), oat flour (0, 5, 10, 15 %) and sorghum flour (85, 70, 55 %) as per the recipe given in Table 1.

Baking characteristics

• The effect of sorghum, oat, and soybean flour additions on biscuit baking scores

Biscuits made with varying amounts of sorghum, oat, and soybean flour (Fig. 1) are shown in Table 2 along



T_0: Sorghum biscuits-100 % sorghum flour;
T_8: 65% sorghum flour + 15% oat flour + 20% soybean flour

Fig. 1: Effect of incorporation of sorghum, oat and soybean flour on baking quality of biscuits.

Table 3: Chemical composition of multigrain biscuits.

Parameters (%)	Sorghum biscuits		Multigrain biscuits	
	(WB± SD)	(DB± SD)	(WB ± SD)	(DB ± SD)
Moisture	3.59 ± 0.06	-	2.87 ± 0.18	-
Protein	7.38 ± 0.50	7.65 ± 0.51	11.69 ± 0.88	12.03 ± 0.89
Ash	1.39 ± 0.02	1.44 ± 0.02	1.65 ± 0.07	1.70 ± 0.07
Fat	26.50 ± 0.45	27.49 ± 0.45	28.56 ± 0.11	29.42 ± 0.06
Crude fibre	1.51 ± 0.03	1.56 ± 0.04	2.57 ± 0.09	2.64 ± 0.09
Carbohydrates by difference	61.15 ± 0.85	63.42 ± 0.91	55.47 ± 1.33	56.85 ± 1.00

Mean of four repetitions; ±SD: Standard deviations;
Sorghum biscuits- 100% sorghum flour;
Formulated- 65% sorghum flour + 15% oat flour + 20% soybean flour

with their physical characteristics. To evaluate biscuit quality, one must consider the spread factor. The biscuits taste better with larger spread ratios. Biscuit height is closely proportional to the spread ratio (up to 15% oat and 20% soybean flour), although biscuit diameter is usually unaffected by increasing the amount of soybean and oat flour. There was a decrease in spread as the protein content in the cookies rose, as documented in (McWatters, 1978; Singh *et al.*, 1993). The biscuits with the highest spread ratio were those that were composed of 65% sorghum flour, 15% oat flour, and 20% soybean flour.

• The effect of sorghum, oat, and soybean flour on the average sensory panel ratings of biscuits on a 9-point hedonic scale

Multigrain biscuits made with varying amounts of sorghum, oat, and soybean flour were tested for their sensory qualities (top grain, texture, flavour, taste, and overall acceptability) and the results are shown in Table 2.

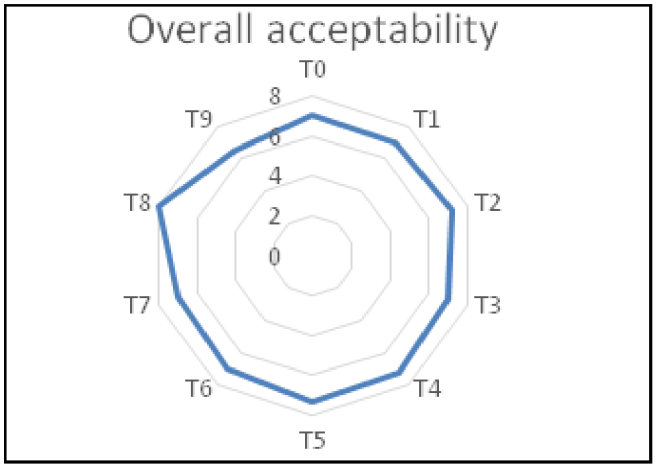


Fig. 2: Effect of incorporation of sorghum, oat and soybean flour on the mean overall acceptability score (9-point hedonic scale) of multigrain biscuits.

Among all the samples, the one with 65% sorghum flour, 15% oat flour, and 20% soybean flour received the highest sensory score from the assessors. Compared to biscuits with smaller amounts of sorghum flour, those with a higher quantity of sorghum flour had detrimental effects on appearance, top grain, taste, flavour, texture, and overall acceptability. Out of all the treatments, the biscuits made with 65% sorghum flour, 15% oat flour, and 20% soybean flour had the highest overall acceptance score (7.99) (Fig. 2). Therefore, in order to bake biscuits for the subsequent storage evaluations, a formulation containing 65% sorghum flour, 15% oat flour, and 20% soybean flour was used.

Proximate composition of biscuits

Proximate composition of the biscuits with 100 % sorghum flour was 3.59 % moisture, 1.39 % ash, 7.38 % crude protein, 26.50 % fat, 1.51 % crude fiber content and 61.15% carbohydrates. Proximate composition of the formulated biscuits was 2.87 % moisture, 1.65 % ash, 11.69 % crude protein, 28.56 % fat, 2.57 % crude fiber content and 55.47 % carbohydrates (Table 3).

Storage study

The biscuits prepared from 65 % sorghum flour, 15% oat flour and 20 % soybean flour were selected as best combination for further storage study based on the spread ratio and overall acceptability scores. Storage study of biscuits prepared from selected level of 65 % sorghum flour, 15 % oat flour and 20 % soybean flour were analyzed for moisture, water activity, hardness, color and sensory

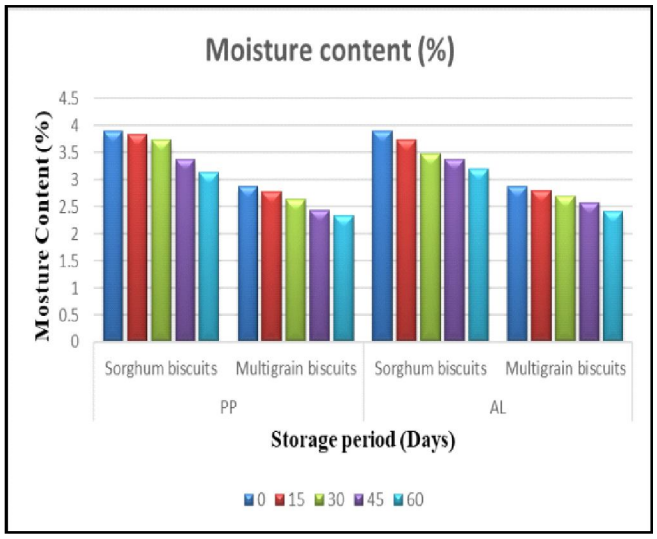


Fig. 3: Effect of storage period on moisture content (%) of multigrain biscuits prepared from sorghum, oat and soybean flour packed in PP and AL.

Table 4: Effect of storage period on moisture content (%), water activity and hardness (kg) of multigrain biscuits prepared from sorghum, oat and soybean flour packed in PP and AL.

Days	Moisture content (%)				Water activity				Hardness (kg)			
	PP		AL		PP		AL		PP		AL	
	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain
0	3.89	2.87	3.89	2.87	0.29	0.26	0.29	0.26	1.03	0.53	1.03	0.53
15	3.83	2.77	3.74	2.79	0.30	0.29	0.32	0.31	1.06	0.66	1.06	0.61
30	3.73	2.64	3.48	2.69	0.34	0.30	0.34	0.31	1.13	0.79	1.14	0.74
45	3.38	2.44	3.37	2.58	0.37	0.32	0.38	0.32	2.64	2.84	2.80	1.45
60	3.14	2.33	3.20	2.41	0.43	0.33	0.39	0.32	3.49	3.21	3.75	1.55

Factor	CD (0.05)	S.Em. ±	CV %	Factor	CD (0.05)	S.Em. ±	CV %	Factor	CD (0.05)	S.Em. ±	CV%
A	0.25	0.09		**A**	NS	0.012		**A**	0.15	0.07	
B	0.25	0.09		**B**	0.03	0.012		**B**	0.15	0.07	
A×B	NS	0.12		**A×B**	NS	0.016		**A×B**	0.21	0.10	
C	0.39	0.14	15.10	**C**	0.05	0.018	11.56	**C**	0.23	0.11	13.29
A × C	NS	0.19		**A × C**	NS	0.026		**A × C**	0.32	0.16	
B × C	NS	0.19		**B × C**	NS	0.026		**B × C**	0.32	0.16	
A×B×C	NS	0.27		A×B×C	NS	0.037		A×B×C	0.46	0.23	

Mean of three repetitions; *NS: Non-significant;*
A: Packaging material (PP- Polypropylene; AL: Aluminum laminates);
B: Treatment (Sorghum biscuits- 100% sorghum flour; Multigrain biscuits- 65% sorghum flour + 15% oat flour + 20% soybean flour);
C: Storage period

quality under ambient condition packed in polypropylene (PP) and aluminum laminates (AL).

Formulations **Sample**

Sorghum biscuits 100 % Sorghum flour

Multigrain biscuits 65% Sorghum flour + 15 % Oat flour + 20 % Soybean flour

• The effect of storage period on the water activity and moisture content (%) of multigrain biscuits made with sorghum, oat, and soybean flour and packaged in PP and AL

Effect of storage period on moisture content (%) of multigrain gluten free biscuits prepared from sorghum, oat and soybean flour were shown in Table 4. Multigrain gluten free biscuits (MGF biscuits) packed in PP and AL packaging material and stored under ambient temperature conditions and their moisture content, water activity, hardness and sensory evaluation were determined after every 15 days of interval over the 60 days of storage period. Moisture content decreased with increasing the storage period.

More decrease in moisture content was observed for biscuits packed in PP as compared to biscuits packed in AL. Also, more loss of moisture was noted for biscuits with 100 % sorghum flour as compared to MGF biscuits. Moisture content for biscuits with 100 % sorghum flour decreased from 3.89 % to 3.14 % and 3.89 % to 3.20 % for PP and AL packaging material respectively. Moisture content for MGF biscuits decreased from 2.87 % to 2.33 % and 2.87 % to 2.41 % for PP and AL packaging material respectively (Table 4, Fig. 3).

The moisture level of MGF cookies varied significantly depending on the packaging material, storage time, and treatment. The interaction of packing materials with treatments did not significantly affect the moisture content of MGF biscuits.

So, the MGF biscuits prepared after incorporation of 65 % sorghum flour, 15 % oat flour and 20 % soybean flour had maximum moisture content. The rate of firming was shown to be inversely proportional to the moisture content, according to Rogers *et al.*, (1988). Bread firmness was found to be considerably affected by moisture content, according to Hoseney and He (1990).

The microbe's water needs were described in relation to its water activity or accessible water. As the storage period was extended, the water activity rose. More increase in water activity was observed for biscuits packed in PP as compared to biscuits packed in AL. Also, more raise in water activity was noted forbiscuits with 100 % sorghum flour as compared to MGF biscuits. Water activity for biscuits with 100 % sorghum flour increased from 0.29 to 0.43 and 0.29 % to 0.33 % for PP and AL packaging material respectively. Water activity for MGF biscuits increased from 0.26 to 0.33 and 0.26 to 0.32 for PP and AL packaging material respectively (Table 4, Fig. 4).

Table 5: Effect of storage period on L-value, a-value and b-value of multigrain biscuits prepared from sorghum, oat and soybean flour packed in PP and AL.

Days	L-value				a-value				b-value			
	PP		AL		PP		AL		PP		AL	
	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain	Sorghum biscuits	Multi-grain
0	75.01	72.58	75.01	72.58	0.76	0.40	0.76	0.40	5.43	7.05	5.43	7.05
15	77.73	73.52	76.97	74.10	1.11	0.49	0.93	0.37	6.27	7.42	7.17	7.19
30	78.66	75.71	78.35	75.41	1.29	0.77	1.02	0.61	6.94	7.75	7.48	7.47
45	80.26	77.03	80.67	77.65	1..35	0.82	1.07	0.74	7.23	8.57	7.56	7.79
60	82.53	80.64	81.61	78.81	1.50	0.91	1.18	0.83	8.28	8.62	7.80	8.01

Factor	CD (0.05)	S.Em. ±	CV %	Factor	CD (0.05)	S.Em. ±	CV %	Factor	CD (0.05)	S.Em. ±	CV%
A	*NS*	0.79		**A**	0.08	0.04		**A**	0.15	0.15	
B	2.25	0.79		**B**	0.08	0.04		**B**	0.15	0.15	
A×B	*NS*	1.11		**A×B**	NS	0.06		**A×B**	0.21	0.22	
C	3.55	1.24	5.57	**C**	0.13	0.06	14.59	**C**	0.23	0.24	11.41
A × C	NS	1.78		**A × C**	NS	0.09		**A × C**	0.32	0.34	
B × C	NS	1.78		**B × C**	NS	0.09		**B × C**	0.32	0.34	
A×B×C	NS	2.49		A×B×C	NS	0.13		A×B×C	0.46	0.48	

Mean of three repetitions; *NS: Non-significant;*
A: Packaging material (PP- Polypropylene; AL: Aluminum laminates);
B: Treatment (Sorghum biscuits- 100% sorghum flour; Multigrain biscuits- 65% sorghum flour + 15% oat flour + 20% soybean flour);
C: Storage period

The water activity of biscuits varied significantly with respect to storage length and treatments. Biscuit water activity varied, but not significantly, in response to treatment-packaging interactions.

Biscuits with 100 % sorghum flour showed more gain in water activity than formulated MGF biscuits with increasing storage period. Additionally, Breene *et al.*, (1988) noted similar findings. Reducing water activity below 0.7 prevents microbiological deterioration, according to Labuz *et al.*, (1972). As the storage time of biscuits rose, their water activity also increased. Frazier (1978) also found similar outcomes in his research. Biscuits made with soybean and oat flour had lower water activity than those made with 100% sorghum flour.

The interaction of packaging material with treatments, treatments with storage period and combined effects of packaging materials, treatments and storage period on hardness of MGF biscuits was found significant. The hardness of MGF biscuits increased with increasing storage period. More increase in hardness was found for biscuits with 100 % sorghum flour as compared to formulated MGF biscuits. Biscuits packed in PP packaging material showed more increase in hardness as compared to biscuits packed in AL packaging material. Biscuits packed in AL remained softer as compared to PP (Table 4, Fig. 5).

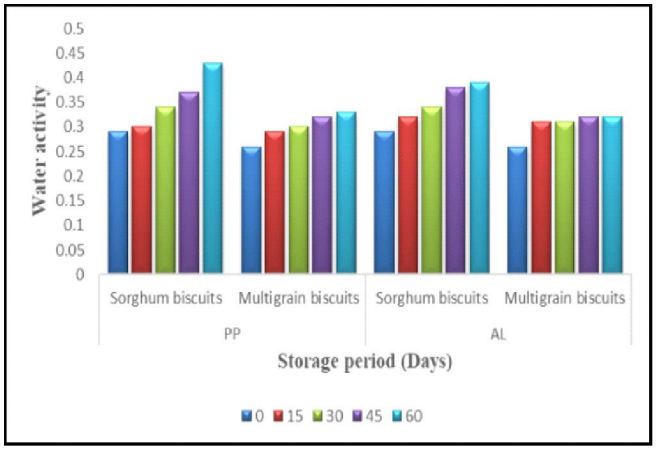


Fig. 4: Effect of storage period on water activity of multigrain biscuits prepared from sorghum, oat and soybean flour packed in PP and AL.

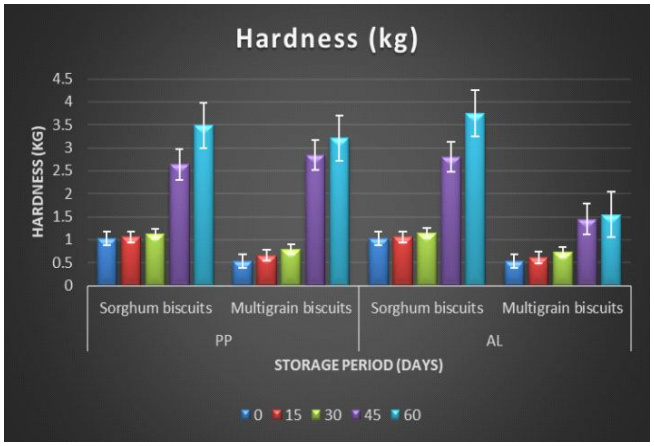


Fig. 5: Effect of storage period on hardness of multigrain biscuits prepared from sorghum, oat and soybean flour packed in PP and AL.

Table 6: Effect of storage period on overall acceptability scores (Max 9) of multigrain biscuits prepared from sorghum, oat and soybean flour packed in PP and AL.

Days	Overall acceptability			
	PP		AL	
	Sorghum biscuits	Multigrain biscuits	Sorghum biscuits	Multigrain biscuits
0	7.11	7.94	7.11	7.94
15	6.82	7.68	7.09	7.84
30	6.73	7.47	7.04	7.45
45	6.42	7.38	7.04	7.33
60	6.27	7.24	6.82	7.15

Factors	CD (0.05)	S.Em.±	CV %
A	0.17	0.08	4.42
B	0.17	0.08	
A×B	0.24	0.12	
C	0.26	0.13	
A × C	*NS*	0.18	
B × C	*NS*	0.18	
A × B × C	*NS*	0.26	

Mean of three repetitions; *NS: Non-significant;* A: Packaging material (PP- Polypropylene; AL: Aluminum laminates); B: Treatment (Sorghum biscuits- 100% sorghum flour; Multigrain biscuits- 65% sorghum flour + 15% oat flour + 20% soybean flour); C: Storage period

• The effect of storage period on the color (L, a, b-value) of sorghum, oat, and soybean flour multigrain biscuits packaged in polypropylene and aluminum foil

Effect of storage period on color (L, a, b-value) of multigrain biscuits prepared from sorghum, oat and soybean flourwas discussed in Table 5. The individual effect of treatments and storage period on L-value biscuits was found significant. L-value for biscuits with 100 % sorghum flour increased from 75.01 to 82.53 and 75.01 to 81.61 for PP and AL packaging material respectively. L-value for MGF biscuits increased from 72.58 to 80.64 and 72.58 to 78.81 for PP and AL packaging material respectively (Table 5).

The interaction of packaging material with treatments, treatments with storage period and combined effects of packaging materials, treatments and storage period on L-value of biscuits was found non-significant. The L-value of biscuits with 100 % sorghum flour and MGF biscuits increased with increasing storage period. More increase in L-value was found forbiscuits with 100 % sorghum flour as compared to formulated MGF biscuits. Biscuits packed in PP packaging material showed more increase in L-value as compared to biscuits packed in AL packaging material. More increase in lightness of biscuits was found for biscuits with 100 % sorghum flour as compared to formulated MGF biscuits. Biscuits packed in PP remained lighter as compared to biscuits packed in AL.

Effect of storage period on a-value of multigrain biscuits prepared from sorghum, oat and soybean flour was discussed in Table 5. The individual effect of packaging materials, treatments and storage period on a-value biscuits was found significant. The a-value for biscuits with 100 % sorghum flour increased from 0.76 to 1.50 and 0.76 to 1.28 for PP and AL packaging material respectively. The a-value for MGF biscuits increased from 0.40 to 0.91 and 0.40 to 0.83 for PP and AL packaging material respectively (Table 5).

The interaction of packaging material with treatments, treatments with storage period, packaging material with storage period and combined effects of packaging materials, treatments and storage period on a-value of biscuits was found non-significant. The a-value of biscuits with 100 % sorghum flour and MGF biscuits increased with increasing storage period. More increase in a-value was found for biscuits with 100 % sorghum flour as compared to formulated MGF biscuits. Biscuits packed in PP packaging material showed more increase in a-value as compared to biscuits packed in AL packaging material. More increase in lightness of biscuits was found for biscuits with 100 % sorghum flour as compared to formulated MGF biscuits.

Multigrain biscuits made with sorghum, oat, and soybean flour were examined in Table 5 for the effect of storage time on the b-value. Results showed that treatments and storage conditions each had a notable impact. The b-value of biscuits was determined to be unaffected by the individual effects of the packing materials.

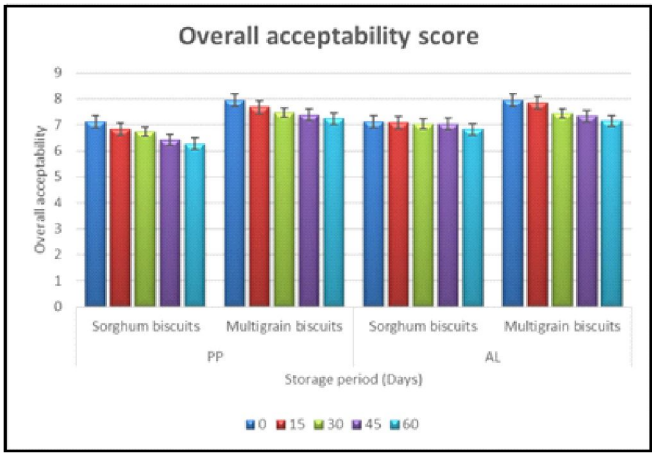


Fig. 6: Effect of storage period on overall acceptability scores (Max 9) of multigrain biscuits prepared from sorghum, oat and soybean flour packed in PP and AL.

The b-value for biscuits with 100 % sorghum flour increased from 5.43 to 8.28 and 5.43 to 7.80 for PP and AL packaging material respectively. The b-value for MGF biscuits increased from 7.05 to 8.62 and 7.05 to 8.01 for PP and AL packaging material respectively (Table 5).

In terms of the b-value of biscuits, there was no statistically significant interaction between packing material, treatments, storage period, or any of the three factors individually or when combined. The b-value of biscuits with 100 % sorghum flour and MGF biscuits increased with increasing storage period. More increase in b-value was found in biscuits with 100 % sorghum flour as compared to formulated MGF biscuits. Biscuits packed in PP packaging material showed more b-value as compared to biscuits packed in AL packaging material.

• The effect of storage period on the overall acceptability scores of PP and AL-packed multigrain biscuits made with sorghum, oat, and soybean flour

For multigrain biscuits made with sorghum, oat, and soybean flour, Table 6 shows the effect of the period of storage on the overall acceptability scores (Hedonic scale). Overall biscuit acceptance was found to be significantly affected by specific factors such as packing materials, treatments, and storage period.

There was also a significant finding regarding the relationship between treatments and packaging material. Overall, there was no statistically significant interaction between treatments, storage time, and packing materials for biscuit acceptability. Equally insignificant was the relationship between storage duration, treatments, and packaging materials. The longer biscuits were kept, the less palatable they became overall. More decrease in overall acceptability score in biscuits with 100 % sorghum flour was found as compared to formulated MGF biscuits. Biscuits packed in AL packaging material showed less decrease in overall acceptability score as compared to biscuits packed in PP packaging material. Biscuits packed in AL remained more acceptable as compared to biscuits packed in PP over the storage period.

Biscuits with 100 % sorghum flour packed in PP and AL packaging materials liked moderately by sensory panelist while MGF biscuits packed in PP and AL packaging materials like very much by sensory panelist. So, MGF biscuits prepared from 65 % sorghum flour, 15% oat flour and 20 % soybean flour were accepted by the sensory panelist in AL and PP packaging material upto 60 days of storage periods.

Biscuits prepared from sorghum flour were accepted by the sensory panelist upto 45 days of storage period because it became too hard due to loss of moisture content. So, biscuits prepared from developed formulations were not suitable for further sensory evolutions after 60 days of storage period. Biscuits prepared from 100 % sorghum flour and developed formulations packed in PP and AL did not show any visible growth (Table 6, Fig. 6).

Conclusions

- MGF biscuits with 65% sorghum flour, 15% oat flour, and 20% soybean flour had a higher spread ratio. Sensory panel accepted it more for colour, appearance, top grain, flavour, taste, and overall acceptability.
- Biscuits made with 65% sorghum flour, 15% oat flour, and 20% soybean flour had the best baking and sensory qualities.
- To examine shelf life, MGF biscuits made with 65% sorghum flour, 15% oat flour, and 20% soybean flour were chosen as the best option.
- Both PP and AL packaging materials showed a decrease in moisture content for MGF biscuits. Dryness rendered the sample unsatisfactory.
- Both PP and AL packaging materials showed an increase in water activity for MGF biscuits. Biscuits with 100% sorghum flour had more water activity than 65% sorghum, 15% oat, and 20% soybean biscuits. During storage, Biscuits with 100 % sorghum flour had more increase in water activity than MGF biscuits.
- MGF biscuit hardness increased with storage time. Biscuits with 100% sorghum flour hardened more than MGF biscuits. Biscuits in PP packaging hardened more than those in AL packaging. AL packed biscuits were softer than PP packed biscuits.
- Biscuits made from developed formulations remained acceptable for 60 days at 30±1°C temperature, while biscuits made from 100% sorghum flour were rejected by sensory panelists after 45 days.
- Biscuits with 65% sorghum flour, 15% oat flour, and 20% soybean flour showed no visible growth up to 60 days of storage, but their sensory properties changed after 60 days.

Declarations

All authors are agreed for the publication of work

*The data and materials are available with author

Conflict of interest: All authors declare that they have no conflict of interest.

The current work has not been published before

It is not under consideration for publication elsewhere,

If accepted, it will not be published elsewhere in the same form, in English or in any other language.

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