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Comparative analysis of biochemical, nutritional and sensory properties of whole wheat flour with oat flour, defatted soy flour and ground flaxseed

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Abstract

This study explores the enhancement of bread's nutritional and sensory attributes by incorporating oat flour, defatted soy flour, and ground flaxseed into whole wheat flour. The Indian bakery industry's significance and structure set the context for this research, highlighting the need for nutritionally enriched bakery products. Various combinations of whole wheat flour (WF), oat flour (OF), defatted soy flour (SF), and ground flaxseed (GFS) were formulated and analyzed for their proximate compositions, including moisture, protein, fat, carbohydrate, dietary fiber, sugar, ash, and mineral content. The formulations tested were 100:0:0:0, 85:5:5:5, 80:10:5:5, 75:15:5:5, 70:20:5:5, and 65:25:5:5 (WF:OF:SF). Bread samples were prepared and evaluated for biochemical, nutritional, and sensory properties using standard AOAC and AACC methods. Results indicated significant improvements in protein, dietary fiber, and mineral content in composite breads compared to the control (100% whole wheat). Particularly, the 70:20:5:5 combination exhibited the highest dietary fiber, ash, iron, and phosphorus levels, while the 65:25:5:5 combination had the highest protein, fat, and calcium content. Sensory evaluation revealed that the bread with 70% wheat flour, 20% oat flour, 5% defatted soy flour, and 5% ground flaxseed scored highest in overall acceptability, flavor, and texture, suggesting a favourable balance of nutritional enhancement without compromising sensory quality. This study demonstrates the potential of using composite flours to produce nutritionally superior bread, which can cater to health-conscious consumers and address nutrient deficiencies. The findings support the development of functional bakery products that are both nutritious and appealing to consumers.

Key word- , Bakery products, Composite flours, Nutritive analysis, Sensory Analysis

INTRODUCTION

The Indian bakery industry is a sector predominantly composed of small-scale enterprises, with an estimated 50,000 small and medium-sized producers and 15 units operating within the organized sector. This industry's nature, which focuses on catering to local tastes and gravitating towards local markets, results in a widely dispersed structure. This dispersion is also influenced by the government's reservation policies favoring small-scale industries. Despite the prevalence of small-scale producers, the organized sector plays a significant role in the industry's output. It accounts for 85% of total bread production and approximately 90% of other bakery products, which collectively are estimated to weigh around 0.6 million tons. The organized sector's substantial share highlights its efficiency and capacity to meet large-scale demand. According to the Ministry of Food Processing Industries, the bakery industry in India is split between the organized sector, which constitutes 15% of the industry, and the informal sector, which makes up 85%. The demand for bread has seen a significant increase, rising from 11.90 billion INR in the fiscal year 2000-2001 to 26.90 billion INR in 2014-2015 (Ministry of Food Processing Industry, 15 July 2012). Bread is an essential component of human diets across various regions due to its rich nutritional profile. It is a valuable source of calories, protein, vitamins, and minerals. Only wheat flour contains gluten, a crucial substance for leavening, which provides the structure necessary for bread to rise (Singh et al., 1978). Bread's status as one of the oldest functional foods has made it a subject of extensive research regarding its health benefits. Functional foods like bread are vital not only for addressing hunger but also for fulfilling health needs by preventing diseases related to nutrient deficiencies. This dual role underscores the importance of bread in both traditional diets and modern health-conscious consumption. (Sharma *et al.*, 1978). Bread is one of the oldest functional foods, with its health benefits thoroughly studied over the years. Functional foods like bread are essential not only for addressing hunger but also for meeting health needs by preventing nutrient deficiency-related diseases (Fernandez-Tome *et al.*, 2023).

Common bakery products like bread, rolls, biscuits, cookies, and pastries are widely consumed. This results in healthier products that are low in calories and cholesterol and suitable for people with conditions like celiac disease and diabetes. Wheat flour is a complex mixture of starch (70-80%), protein (8-18%), lipid (2%), pentosans (2%), enzymes, enzyme inhibitors, and other minor components (Devis *et at*., 1984). The technological significance of wheat flour primarily comes from its gluten protein, a water-insoluble complex protein with unique viscoelastic properties, essential for bread's texture and structure (Gu, 2022; Gutowski, 2020). Soybean, originating from ancient China, is a versatile food source, often called the 'Miracle bean,' 'Golden bean,' 'Nugget of Nutrition,' and 'Cow of China.' It is composed of approximately 40% protein and 21% oil, with the remaining third consisting of non-starchy carbohydrates like polysaccharides, stachyose, raffinose, and sucrose (Udomkun, 2022). Soybean protein is rich in lysine and tryptophan but low in sulfur-containing amino acids (Kim, 2022). Oats (Avena sativa) are among the most nutritious cereals for human consumption. Oatmeal, made by removing the husk, is a common breakfast food (porridge) in Europe. Oats are unique among cereals for containing avenalin, a globulin or legume-like protein, as the major (80%) storage protein. The composition of Indian oatmeal includes moisture (10%), protein (13.6%), fat (7.6%), carbohydrates (62.8%), and ash (1.8%). Flax seeds, from the Linaceae family and botanically named Linum usitatissimum, are ancient crops grown for their oil seeds and fiber. These seeds are nutrient-dense, containing omega-3 fatty acids, antioxidants, minerals, and essential vitamins. Flax seeds are used in cooking and as a base oil in traditional medicines and pharmaceuticals. Supplementing cereals and pulses can enhance bread's nutritional quality by increasing dietary fiber and protein while lowering carbohydrate content. Developing new bread formulations requires laboratory testing and consumer acceptance. There is a growing demand for bread with better nutrition and texture.

MATERIAL AND METHODS

Whole Wheat flour, Oat flour, defatted Soy flour, ground flax Seeds and other material required for bread making were purchased from domestic market and analytical chemicals were procured from scientific stores.

Preparation of composite flours

Evaluating the proximate compositions of the flour used in this study was essential before developing a new formulation for a dietary fiber and protein-rich bakery product. The proximate analysis of the samples was conducted according to the standard AOAC method (AOAC, 1990). This analysis included measurements of moisture, crude protein, crude fat, ash, carbohydrate (by difference), dietary fiber, sugar, and minerals. All measurements were performed in triplicate.

Preparation and formulation of bread samples

Preparation of bakery product rich in dietary fiber and protein, we replaced a portion of wheat flour (WF) with oat flour (OF), defatted soy flour (SF), and flax seeds (FS) at various levels: 100:0:0:0, 85:5:5:5, 80:10:5:5, 75:15:5:5, 70:20:5:5, and 65:25:5:5.

Sponge Preparation:

- 50 g wheat flour
- 15 g sugar
- 7.6 g instant yeast
- 100 ml water

These ingredients were mixed thoroughly to form the sponge mixture.

Dough Ingredients:

- 350 g wheat flour
- 20 g sugar
- 16 g milk powder
- 9 g improver
- 5 g salt
- 28 g shortening
- Water (amount determined using the Farinograph water absorption method)

Dough Preparation:

1. Combine the sponge mixture with the dough ingredients.
2. Mix in a Spar mixer (SP-800, Taichung Hsien, Taiwan) until a smooth and elastic dough is formed.
3. Let the dough rest at 37°C and 85% relative humidity in a proofer for 40 minutes.

Shaping and Baking:

1. Manually shape the rested dough and place it in an aluminum baking pan.
2. Allow the dough to proof for an additional hour.
3. Bake the dough in an oven at 180°C for 20 minutes.
4. Cool the baked loaf at room temperature for one hour before analysis.

This method ensures the development of a bakery product that is both rich in dietary fiber and protein.

Flow chart –

All the ingredients are mixed together for 30 minutes
(Flour, sugar, salt, baking powder, soda, yeast, water etc.)
↓
Proofing (28-37˚C) for 40 minutes
↓
Kneading and punching (5 min) by hand to remove gases (knock back)
↓
Greasing & Dusting
↓
Sheeting/ moulding

↓
Proofing (28-37˚C temperature for 60 minutes)
↓
Baking (180˚C for 20 to25 minutes)
↓
Cooling (at room temperature)
↓
Packing (Food grade polythene)
↓
Storage
(1. Room temperature 35˚ – 37˚ C)
(2. Refrigerated temperature 4˚ C)

Table 1. Formulation of different combinations

Ingredient	Control	85:05:05:05	80:10:05:05	75:15:05:05	70:20:05:05	65:25:05:05
Bread flour (g)	100	85	80	75	70	65
Icing Sugar (g)	10	10	10	10	10	10
Salt (g)	2	2	2	2	2	2
Instant Yeast (g)	5	5	5	5	5	5
Water (ml)	65 – 66	65 – 66	65 - 66	65 - 66	65 - 66	65 - 66

*(WF:OF:SF:GFS):Wheat flour, Oat flour, Soya flour and Ground Flax Seeds

2.3. Chemical Analysis

All chemical analysis were analysed according to the AACC (2000) and AOAC methods (1990).

2.3.1. Carbohydrates (by Difference)

To determine pigment content, 10 g of flour was placed in a 125 ml flask, and 50 ml of H2O-saturated n-butyl alcohol was added using a pipette. The flask was tightly stoppered, shaken well for 1 minute, and allowed to stand for 15 minutes, protected from sunlight. It was reshaken, filtered through a 12.5 cm folded paper (Eaton-Dikenman Co. No. 192, or equivalent), and the filtrate was collected in a 50 ml Erlenmeyer flask or suitable container. A 1 cm cell was filled with flour extract and a duplicate cell with the corresponding solvent. Absorbance at 435.8 nm was read using a spectrophotometer, and pigment as carotene in ppm was calculated (AOAC, 1990).

Mineral Analysis

For the determination of minerals such as calcium, phosphorus, and iron, acid-soluble ash was used. (Ranganna, 1986).

Sensory Evaluation

The sensory evaluation of bread was conducted using a 9-point hedonic score system (Meilgaard et al., 2007).

Statistical Analysis

The data obtained were analysed statistically using ANOVA to determine if the differences were significant. For physical characteristics of wheat flour and sensory parameters of bread, the average of replications was determined as mean with a critical difference at the 5% level.

RESULTS AND DISCUSSION

The results from the proximate and mineral analyses of whole wheat flour, oat flour, soy flour, and ground flaxseed are shown in Tables 2 and 3. These results were consistent with those reported in the literature (Weiss, 2000). The chemical composition of the composite flours affected both the chemical and mineral properties of their products (Dhingra and Jood, 2006;).

Nutritional Properties of Whole Wheat Flour, Oat Flour, Soy Flour, and Ground Flaxseed Blends

Moisture Content

Wheat flour contained 10.73% moisture, within the range reported by various studies (Bain and Irvin, 1965; Tara et al., 1969; Rao, 1969). The moisture content of the uncooked mixturediverse abundantly, and the variation was significant ($P<0.05$). Oat flour, soy flour, and ground flaxseed had lower moisture content than whole wheat flour.

Crude Protein

The protein content in whole wheat flour and oat flour was 13.5% and 14.48%, respectively, consistent with the range reported in previous studies (Bell and Simmonds, 1963). The protein content of the uncooked mixturediverse abundantly, with significant variation ($P<0.05$) compared to whole wheat flour. However, the variation among the blends was not significant, indicating higher protein content in blends due to the higher albumin and globulin proteins in oat flour, soy flour, and ground flaxseed (Fernandez-Tome, 2023).

Crude Fat

The fat content in whole wheat flour and oat flour was 2.13% and 9.16%, respectively, within the range reported by other studies (Singh et al., 1978; Popli & Dhindsa, 1980). The fat content of the uncooked mixture diverse abundantly, with significant variation ($P<0.05$) in blends containing 5% and 25% oat flour.

Carbohydrates Content

The carbohydrate content in whole wheat flour and oat flour was 72.10% and 67.09%, respectively. The carbohydrate content of the uncooked mixturediverse abundantly, with significant variation ($P<0.05$) compared to whole wheat flour.

Dietary Fiber

The dietary fiber content in whole wheat flour and oat flour was 11.51% and 11%, respectively. The dietary fiber content of the uncooked mixturediverse abundantly, with significant variation ($P<0.05$) compared to whole wheat flour.

Total Sugar Content

The sugar content in whole wheat flour and oat flour was 0.36% and 0.75%, respectively, with higher values reported by Hooda and Jood (2005). The sugar content of the uncooked mixturediverse abundantly, with significant variation compared to whole wheat flour.

Total Ash

The ash content in whole wheat flour and oat flour was 1.54% and 1.97%, respectively, within the range reported by other studies (Rao et al., 1976). The ash content of the uncooked mixturediverse abundantly, with significant variation compared to whole wheat flour.

Calcium Content

The calcium content in whole wheat flour and oat flour was 34 mg/100g and 54.9 mg/100g, respectively, with values consistent with previous reports (Dogra et, al., 2004). The calcium content of the uncooked mixture diverse abundantly, with significant variation ($P<0.05$) compared to whole wheat flour.

Iron Content

The iron content in whole wheat flour and oat flour was 3.98 mg/100g and 3.5 mg/100g, respectively, within the range reported by other studies (Davis et al., 1984). The iron content of the uncooked mixture diverse abundantly, with significant variation compared to whole wheat flour.

Phosphorus Content

The phosphorus content in whole wheat flour and oat flour was 345 mg/100g and 426 mg/100g, respectively, consistent with previous studies (Tara et al., 1969; Popli & Dhindsa, 1980). The phosphorus content of the uncooked mixture diverse abundantly, with significant variation ($P<0.05$) in blends containing 5% and 25% oat flour.

Table 2. Chemical and minerals characteristics of whole wheat flour, defatted soy flour, oat flour and flaxseeds blends:

Parameters	**Whole Wheat Flour**	**Defatted Soy Flour**	**Oat Flour**	**Ground Flaxseed**
Moisture(gm/100g)	10.48±1.14	8.99±1.66	9.22±1.98	6.08±1.84
Protein(gm/100g)	13.01±2.03	51.83±2.48	17.02±2.70	20.90±2.73
Fat(gm/100g)	3.23±1.33	2.05±1.07	10.94±1.98	45.10±2.65
Ash(gm/100g)	2.58±1.32	7.74±1.45	4.04±1.97	8.21±1.86

Carbohydrates(gm/100g)	80.32±7.74	39.53±3.14	70.61±3.74	31.23±3.06
Dietary Fiber(gm/100g)	12.35±2.08	15.77±2.15	13.33±2.52	29.33±1.84
Sugar(gm/100g)	0.81±0.40	20.77±3.69	1.54±1.01	4.33±1.66
Calcium(mg/100g)	37.73±3.42	348.00±96.38	65.47±9.38	304.90±70.87
Iron(mg/100g)	5.19±1.10	10.46±1.19	4.60±1.15	7.60±1.88
Phosphorus(mg/100g)	415.33±72.06	719.53±75.29	478.33±45.94	749.20±83.78

Nutritional properties of high fiber bread using different combination of wheat flour, Oat flour, Soy flour and ground flaxseed

Table 3. shows us a comparative study about the proximate analysis of different combinations prepared using the flours. The combination with high content of wheat flour (85:05:05:05) shows high moisture content compared to other combinations. The protein content and fat content are high in the combination with more wheat and oat flour (65:25:05:05) whereas carbohydrate content is low in this combination than others. Dietary fiber is highest in the combination of (70:20:05:05). Ash content shows the presence of minerals in the product which is highest in (70:20:05:05). The two most prominent combinations amongst all are (65:25:05:05) and (70:20:05:05). The combination of flour (70:20:05:05) is rich in dietary fiber, ash, iron and phosphorus while the combination (65:25:05:05) has high content of protein, fat and calcium.

Table3. Proximate minerals composition of high fiber bread using different combination of wheat flour, Oat flour, Soy flour and ground flaxseed

Bread (WF:OF:SF:GFS)						
Parameters	**100:00:00:00**	**85:05:05:05**	**80:10:05:05**	**75:15:05:05**	**70:20:05:05**	**65:25:05:05**
Moisture (%)	11.68±1.08	12.04±1.94	10.92±1.33	10.77±1.24	10.88±1.24	10.65±1.29
Protein (%)	15.37±1.70	16.82±1.25	17.40±1.87	17.03±1.40	17.39±1.83	17.91±2.19
Fat (%)	3.52±1.42	5.82±1.26	6.63±1.80	6.82±1.65	7.18±1.84	7.68±2.19
Carbohydrate (%)	76.44±4.74	71.64±3.90	70.65±3.19	70.85±3.60	70.67±3.07	69.74±2.54
Sugar (%)	0.81±0.39	2.51±1.06	2.97±1.79	2.71±1.37	3.37±2.24	3.05±2.01
Dietary fiber (%)	12.73±1.17	14.39±1.95	13.53±1.46	14.87±2.69	14.97±2.83	14.37±2.34
Ash (%)	2.81±1.29	4.20±1.99	4.66±2.58	4.38±2.22	5.16±2.94	4.47±2.19
Ca(mg/100gm)	38.33±4.51	59.80±4.45	59.80±3.50	61.07±3.65	62.79±4.72	64.32±5.16
Fe(mg/100gm)	4.95±1.10	5.72±1.38	6.94±2.74	6.94±2.73	6.98±2.79	6.54±2.38
P(mg/100ml)	384.33±37.22	429.03±47.30	441.20±55.47	454.00±61.20	479.78±86.69	471.37±74.08

Effect of blending on sensory characteristics. A laboratory panel consisting of 10 untrained panel evaluated bread for sensory attributes as colour, flavor, texture, taste and overall acceptability along with statistical analysis of bread made from different blends consisting of wheat flour, oat flour, defatted soy flour and ground flaxseed for colour, flavor, texture, taste and overall acceptability respectively are shown in Table 4. Sensory value for colour of bread obtained from control (whole wheat flour) and made from the blends containing 70% wheat flour, 20% oat flour, 5% defatted soy flour and 5% ground flaxseed was maximum, however, the inclusion of oat flour up to 25 % did not decrease the colour significantly. The bread obtains from the blends containing 5% and 25 % oat flour lowered the colour value significantly with respect to control bread and the bread containing 20 % oat flour, however, the breads prepared from all the blends are in accept Table range on a 9-point hedonic scale. Results presented in the Table 4. show that the mean sensory value for flavor of bread obtained from control (whole wheat flour) and made from the blends containing 70% wheat flour, 20% oat flour, 5% defatted soy flour and 5% ground flaxseed and made from control are maximum. The bread obtains from the blends containing 5, 10,15 and 25 % oat flour differed significantly with respect to control bread and the bread containing 20 % oat flour, however, the breads prepared from all the blends are in accepted Showed range on a 9-point hedonic scale.

Sensory evaluation of bread made from the blends of whole wheat flour, oat flour, defatted soy flour and ground flaxseed:

The result in the Table 4. presented the effect of oat flour inclusion on texture of bread. The mean sensory value for the bread containing 20% oat flour was maximum however; the variation in mean sensory value for texture was not significant with control sample. The mean sensory value for texture of the bread containing 20%oat flour was significantly higher than other samples except control sample, however, all the samples were in acceptable range on a 9-point hedonic scale. The bread containing 5% oat flour had minimum mean sensory value for texture. The bread containing 10, 15 and 25% oat flour did not differ significantly with each other. The result in a Table 4. presented the effect of oat flour inclusion on the taste of bread. The product obtained from 20% oat flour included blend showed maximum mean sensory value and it was significantly higher from the product obtained from the blends containing 5, 10, 15 and 25 % oat flour., however, the variation with control was non- significant. The mean sensory value for taste of bread obtained from 5, 10, 15 and 25 % oat flour included blends did not differ significantly with each other. The result in the Table 4. reported the effect of oat flour inclusion on the overall acceptability of the bread. The sensory value for overall sensory value of bread made from the blends containing 20% oat flour scored highest for mean overall sensory attributes and the variation was significant with respect to other samples except the control sample. The variation in mean sensory for overall acceptability was not significant in the bread prepared from the blends containing 5, 10, 15 and 25% oat flour.

Table 4. Sensory evaluation of different bread samples

	Bread (WF:OF:SF:GFS)					
Parameters	**100:00:00:00**	**85:05:05:05**	**80:10:05:05**	**75:15:05:05**	**70:20:05:05**	**65:25:05:05**
Colour	8.1±0.46	7.7±0.35	8.0±0.24	8.0±0.24	8.1±0.39	7.9±0.21
Texture	8.2±0.54	6.7±0.54	7.1±0.77	7.4±0.52	8.6±0.46	7.3±0.48
Flavour	8.1±0.46	7.7±0.35	8.0±0.24	8.0±0.24	8.1±0.39	7.9±0.21
Taste	8.3±0.59	7.1±0.66	7.2±0.67	7.7±0.59	8.6±0.39	7.4±0.52
Overall acceptability	8.2±0.48	7.2±0.35	7.4±0.70	7.75±0.26	8.55±0.37	7.38±0.36

CONCLUSION

The study aimed to develop a nutritionally superior bread by blending oat flour, defatted soy flour, and ground flaxseed with whole wheat flour. The goal was to create a bread that is balanced in nutrition, high in fibre, and rich in protein, leveraging the complementary protein qualities of cereals and pulses. The incorporation of these ingredients significantly increased the nutritional profile of the whole wheat flour, elevating levels of essential minerals such as calcium, iron, and phosphorus. Sensory evaluation indicated that the most suitable blend for bread-making included up to 25% oat flour, with the 20% level being particularly notable for acceptability. The inclusion of these ingredients resulted in a nutritionally superior bread blend, high in dietary fibre and protein. The sensory characteristics of the bread were favourable, particularly at the 20% incorporation level of oat flour. This blend can be effectively used in baking to produce bread that meets dietary fibre and protein requirements. The increased fibre content is beneficial for digestive health and can aid in maintaining a healthy weight. The combination of different flours enhances the protein quality, making the bread a better source of essential amino acids. Higher levels of calcium, iron, and phosphorus support bone health, oxygen transport, and energy metabolism. This study supports the idea that blending different flours can create more nutritious bread, suitable for health-conscious consumers looking for enhanced dietary fibre and protein intake.

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