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Original article

Addition of *sesamum indicum* protein isolates improves the nutritional quality and sensorial attributes of wheat flour muffins

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Summary. In the present research, efforts were made to enhance protein content of muffins using non-conventional protein sources. In this context, wheat flour was enriched with varying levels (5, 10, 15, 20 and 25%) of sesame protein isolates (SPI). Flour blends were used to prepare protein enriched muffins that were further evaluated for chemical composition, gross energy, color & textural analysis, and sensorial appraisal. The results were quite conclusive that nutritional quality of the muffins was improved with addition of SPI. Moreover, color analysis showed decreasing trend for L* & b* value, chroma and hue angle, while increasing trend was noticed for a* value. Likewise, the texture profile of muffins showed that firmness increased while elasticity decreased with gradual increase in protein contents. Sensory evaluation showed that muffins containing 15% SPI were rated better by the trained panelists. Conclusively, owing to high nutritive value and balanced nutritional profile, the use of sesame protein isolates can be handy tool to improve the nutritional quality of wheat based bakery products. These protein enriched products *i.e.* muffins can also help to fulfill the nutritional requirements of masses especially in developing countries.

Key words: sesame protein isolates, enriched flours, muffins, nutritional quality, sensory evaluation

Introduction

Proteins being integral parts of healthy diet are involved in various physiological functions as their adequate intake ensures proper growth and development of the body (1). Quality and quantity of proteins utilized in daily diet can be enhanced by the incorporation of non-conventional protein sources in numerous diet formulations *i.e.* addition in wheat (2). High quality proteins play an important role in maintaining better health of an individual. Wheat flour is the potential ingredient of cereal based products. However, it is deficient in lysine which designates that protein quality of wheat flour is not up to the mark. Therefore, to improve the nutritional value of food commodities, it is mandatory to enrich them with high quality proteins (3). Purposely, the proteins obtained from animal sources are of high quality as compared to plant sources (4). Nonetheless, increasing cost and insufficient provision of animal proteins have diverted the interest of food processors towards high protein oilseeds. These non-conventional protein sources also hold interactive properties with other food components like water and lipids (5).

The sesame (*Sesamum indicum* L.) is a major oilseed crop that belongs to the Pedaliaceae family mostly cultivated in tropical areas. Sesame seed is mainly used for the extraction of edible oil with an oil extraction up to 47.8-52.2%. Additionally, it is also used in the preparation of numerous snacks, bakery and confectionary products (6). The fat free meal obtained after oil extraction exhibits a reasonable proportion of high quality proteins that can be potentially utilized as functional ingredient in various food commodities and nutritional supplements. The sesame meal acquired after extraction of oil is a rich protein source *i.e.* about 50% and primitively utilized as animal feed (7).

The development of composite flours using sesame protein isolates can be a way forward to prepare different protein enriched bakery products *i.e.* biscuits, muffins etc. However, in leavened products, increase in protein content may affect the gluten network that ultimately effects the formation and other attributes of final product. Muffins exhibit porous structure with high volume, therefore, considered as soft product with spongy texture. Moreover, the demand for muffins is increasing especially due to better quality and textural attributes. Muffins being sweet and high-energy bakery products are extremely liked by the consumers owing to their excellent taste and textural attributes. Keeping in view the above-mentioned facts, the present study is aiming to serve the individuals with high protein diet by adding sesame protein isolates.

Materials and methods

Preparation of protein isolates

For the preparation of protein isolates, sesame seeds were ground into fine powder and then defatted using soxtec system (Model: H-2 1045 Extraction Unit, Hoganas, Sweden) and hexane as solvent (8). The defatted sesame powder was dispersed in distilled water (1/10) along with pH adjustment at 9.5. Later, centrifugation was carried out at 4000 rpm for 20 min to separate the supernatant. The collected supernatant was adjusted to pH 4.5 for protein precipitation followed by re-centrifugation, neutralization and freeze drying (9). The prepared protein isolates in powder form were packed in plastic bags and stored for further use in air tight containers.

Preparation of protein enriched muffins

Different blends of enriched flours were prepared by replacing straight grade flour with sesame protein isolate as mentioned in Table 1. The muffins were prepared using flour blends (10). The muffins were evaluated for physicochemical analyses, nutritional value and sensory response. Initially, the eggs were beaten for 2 minutes and then mixed with other wet ingredients *i.e.* oil and milk. Afterwards, the dry ingredients like flour, sugar and baking powder were mixed in a separate bowl. The muffin batter was prepared by combining the wet and dry ingredients.

Table 1. Treatments used in the study

Treatments	Wheat flour (%)	Sesame protein isolates (%)
T_0	100	0
T_1	95	5
T_2	90	10
T_3	85	15
T_4	80	20
T_5	75	25

Butter paper was placed in muffin pans and then batter was placed. Each pan filled with 1/2 to 2/3 of batter. Afterwards, muffin pans were placed in the oven and baked at 175°C for 15-20 minutes. After baking, muffins were cooled at room temperature.

Proximate analysis of protein enriched muffins

The prepared muffins were analyzed for moisture (AACC, 2000, Method No. 44-15 A), crude fat (Method No. 30-10), crude protein (Method No. 46-10), crude fiber (Method No. 32-10), ash (Method No. 08-01) and nitrogen free extract (NFE) (11).

Gross energy

The calorific value (CV) of the protein enriched muffins was estimated by using Oxygen Bomb Calorimeter (C-2000, IKA WERKE) (8). The sample (0.5 g) was weighed and placed in calorimeter bucket, after internal burning at high pressure the energy generated by the combustion was measured by the instrument.

Physical analysis of protein enriched muffins

Color analysis

The crust & crumb color profile of muffins was determined in terms of L*, a* & b* values; L* value measuring lightness, a* value measuring redness/greenness and b* value measuring yellowness/blueness using Hunter Lab mini-Scan XE Plus colorimeter (Model

45/0-L, HAL, USA) (12). Chroma (C) and hue angle (h°) were calculated by the following formula:

$$C = [a^{*2} + b^{*2}]^{1/2}$$

$$ho = \tan^{-1}(b^*/a^*)$$

Textural analysis

Texture of protein enriched muffins was measured with a TA.XT2i Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK) according to the American Institute of Baking's (AIB, Manhattan, KS) Standard Procedure for Muffin Firmness and Elasticity (AACC method No. 74-09) (10). It is an automatic equipment having software attached that gives measurements of firmness and elasticity of muffins to bend or snap. The conditions for texture analyses were as follows: force in compression test mode, 1.0 mm/s-test speed, 7.0-mm distance, 5-g force, 32-s duration and 1.27 cm (0.5 in.) hemispherical plastic probe.

Volume

Muffin volume was measured by rapeseed displacement method (11). The muffin was placed in the container filled with rapeseeds and the volume of rapeseeds displaced by the muffin was noted (13).

Sensory evaluation

The muffins were evaluated for color, flavor, taste, texture and overall acceptability by consumer panel using 9-point hedonic scale (14). Purposely, 9 panelists (25 to 45 years age) were given training to perform sensory evaluation through simple orientation. Panelists were selected based solely on interest, time availability, willingness and lack of allergies to food ingredients used in the muffins under study. The individual rating *i.e.* liked extremely-9 to disliked extremely-1 were used to find out the most acceptable composition of muffins. In each session, panelists were seated in separate booths equipped with white fluorescent light in the Sensory Evaluation Laboratory at the National Institute of Food Science and Technology. The panelists were requested to express their opinion about the end product by assigning scores to respective attributes. During sensory session, four muffins from each treatment were served to the panelists. Serving order was determined by following the permutation principle. Purposely, the muffins made from different flour blends were labeled with three digit random codes. Mineral water and unsalted crackers were supplied to the panelists to rinse their mouths and neutralize the taste buds between samples.

Statistical Analysis

The collected data in triplicates was statistically analyzed using Statistical Package (Costat-2003, Co-Hort, v 6.1.). Accordingly, level of significance was estimated by analysis of variance (ANOVA) using completely randomized design (CRD). Means and standard deviations were calculated for different attributes. Consumer panel results were also analyzed using paired t-tests. All tests were done at a statistical significance of $P \leq 0.05$ (15).

Results and discussion

Chemical analysis of protein enriched muffins

The moisture content of muffins (Table 2) ranged from 11.09±0.48 to 11.25±0.30% reflecting non-momentous increase in moisture level. The increasing level of SPI in wheat flour blends also improved the quantity of protein in muffins. The results regarding protein content of muffins revealed significant variations among treatments with varying levels of sesame protein isolates. The highest protein content (12.81±0.17%) was noticed in muffins with 25% SPI addition. Moreover, muffins prepared from flour with 20% SPI showed 11.68±0.50% protein content. Furthermore, muffins having 15% SPI exhibited protein content as 10.55±0.24% while, treatments with 10% and 5% SPI levels presented protein contents as 9.42±0.46% and 8.29±0.30%, respectively. The lowest value for protein content was noticed in control (7.16±0.36%) having 100% wheat flour with no SPI.

The non-significant variations were recorded in fat contents that varied from 29.20±0.68 to 29.29±1.12%. Similarly, trend was recorded in crude fiber contents and values for fiber ranged from 0.65±0.01 to o.69±0.04%. Mean values for ash content varied from 0.90±0.05% (T_5) to 0.93±0.04% (T_0). Likewise, the highest nitrogen free extract (NFE) value 50.75±0.44% was noted in T_0 (control) whereas, minimum in T_5 (45.35±2.61%). Furthermore, the lowest gross energy 422.00±10.24 kcal/100g was noticed in T_0 (control) whilst the highest value was reported in T_5 439.59±4.57 kcal/100g as given in Table 2.

According to best of author's knowledge, enrichment of wheat flour with the sesame proteins is conducted for the first time. The slight upsurge in moisture content may be due to increased quantity of polar amino acids and the effect of proteins on water holding capacity (16). Moreover, the increased moisture might be due to the presence of fiber content during baking. The recent findings regarding protein content of muffins are in accordance with the outcomes of Lipilina and Ganji (17), revealed an increasing trend for protein content (6.40 to 8.4%) of muffins made by substituting wheat flour with ground flaxseed. Likewise, similar rise in protein content (11.90%) was observed by the incorporation of roasted flaxseed powder.

The fat content of food is an important parameter to evaluate its physical and sensory attributes *i.e.* texture, flavor, appearance and mouth-feel. Previously, Goswami et al. (12) described 16.86% fat content in control muffins while 16.92% in barnyard millet flour based muffins. The results could be different from other scientific interventions e.g. Chetana et al. (18) documented that total dietary fiber increased (3.1 to 18.3%) in muffins by the addition of raw and roasted flaxseed powder. Likewise, the ash content of muffins prepared from composite flours supplemented with raw and roasted flaxseed powder increased from 0.8 to 1.3%. The present findings for gross energy are in line with the outcomes of Lipilina and Ganji (17), they found that the energy values varied from 232 to 236 kcal/100g for ground flaxseed incorporated muffins.

Physical analysis

Color

The means for lightness (L*), color (a*, b* value), chroma (C) & hue angle (ho) of the crust and crumb are presented in figures 1 and 2, respectively. The L* values for crust decreased gradually among the treatments with highest value exhibited by T_0 (44.52±2.49) followed by T_1 (41.26±0.74), T_2 (38.50±0.47), T_3 (35.98±1.40) and T_4 (32.84±0.29) whilst, the lowest value was observed for T_5 (30.12±1.88). Similar trend was noticed for L* values of crumb that declined from 30.73±1.01 (T_0) to 17.88±0.92 (T_5). This decrease in lightness can be attributed to the dull color of SPI. Additionally, decrease in crumb lightness might also be due to increase in fiber content of muffins.

The redness (a* value) of crust also increased significantly from 15.03±0.81 in T_0 (control) to 18.48±0.72 in T_5. Similar results were observed for redness (a* value) of crumb with values ranging from 11.02±0.45 (T_0) to 8.45±0.37 (T_5). Nevertheless, a significant decrease in yellowness (b* value) of crust and crumb was noted. The b* values for crust varied from 21.23±0.61 in control muffins (T_0) to 12.79±0.06 in T_5 (75% SGF and 25% SPI). This decrease in redness (a* value) and yellowness (b* value) of muffins may be attributed to color of SPI.

Moreover, the chroma and hue angle of muffins also decreased significantly by increasing the level of SPI. The results indicated that chroma for crust decreased from 26.01±0.43 (T_0) to 22.48±0.17 (T_5) whereas for crumb, the values were 20.44±0.48 (T_0) and 11.48±0.17 (T_5). Likewise, for hue angle of

Table 2. Proximate composition (%) and Gross energy of protein enriched muffins

Treatments	Moisture	Crude protein	Crude fat	Crude fibre	Ash	NFE	Gross Energy (kcal/100g)
T_0	11.20±0.46a	7.16±0.36f	29.29±1.12a	0.67±0.02b	0.93±0.04a	50.75±0.44a	422.00±10.24a
T_1	11.21±0.41a	8.29±0.30e	29.27±0.29a	0.67±0.01b	0.93±0.05a	49.63±2.26b	424.73±10.15a
T_2	11.23±0.48a	9.42±0.46d	29.25±1.30a	0.68±0.02ab	0.93±0.03a	48.49±1.64c	428.44±4.87a
T_3	11.24±0.22a	10.55±0.24c	29.23±0.90a	0.69±0.02a	0.93±0.07a	47.37±1.90d	431.68±19.98a
T_4	11.25±0.30a	11.68±0.50b	29.21±1.13a	0.69±0.04a	0.93±0.02a	46.24±0.81e	436.13±2.18a
T_5	11.09±0.48a	12.81±0.17a	29.20±0.68a	0.65±0.01c	0.90±0.05a	45.35±2.61f	439.59±4.57a

Means sharing the same letters in a column are not significantly different

T_0= 100% Straight grade flour (SGF); T_1 = 95% SGF and 5% SPI; T_2 = 90% SGF and 10% SPI; T_3 = 85% SGFand 15% SPI; T_4 = 80% SGF and 20% SPI; T_5 = 75% SGF and 25% SPI

crust, the values exhibited by various treatments were T_0 (54.70±1.31), T_1 (51.55±0.94), T_2 (48.62±0.80), T_3 (45.34±0.61), T_4 (41.10±0.29) and T_5 (34.69±0.33). Furthermore, similar trend was observed for hue angle of crumb with values ranging from 57.39±1.32 (T_0) to 42.63±0.24 (T_5). These changes in color did not affect the sensory acceptability of muffins enriched with SPI. The present outcomes are in agreement with the findings of Shearer and Davies (10), explicated that L* value for flaxseed meal supplemented muffins decreased from 52.04 to 50.53. Similarly, a* and b* values differed from 6.28-6.74 and 15.94-15.84, respectively.

Texture and Volume

The means for firmness indicated a momentous increase with increasing level of SPI among the treatments as depicted in figure 3. The highest value was revealed by T_5 (115.62±2.62) while the lowest was noted in T_0 (90.42±2.91). Increase in firmness of muffins might be attributed to less availability of water and higher quantity of proteins. Contrarily, elasticity showed a decreasing trend among the treatments with the highest value 59.97±2.31 for T_0 followed by T_1 (55.94±2.82), T_2 (51.49±2.27), T_3 (47.68±2.30) and T_4 (44.10±1.30) whilst, the lowest value was observed for T_5 (40.38±1.02). Likewise, a gradual decreasing trend was noticed among the treatments regarding volume of muffins. The maximum volume was exhibited by T_0 (145.00±2.69 cm^3) followed by T_1 (140.00±2.17 cm^3), T_2 (135.00±0.23 cm^3), T_3 (130.00±6.98 cm^3) and T_4 (125.00±8.82 cm^3) while the minimum value was observed in T_5 (120.00±3.97 cm^3).

The instant outcomes are in concordance with the findings of Shearer and Davies (10), they elucidated that maximum force for flaxseed meal supplemented muffins increased from 396.9 to 594.9 g with increasing levels of flaxseed meal. This force depicts the firmness of muffins. Sesame being an oilseed is comparable with the flaxseed. Moreover, increase in percentage of sesame protein isolates in muffins causes increase in their firmness. However, the elasticity of muffins showed a decreasing trend with values varying from 60.2 to 55.4%. Likewise, Jauharah et al. (19) revealed increasing trend for the hardness of muffins incorporated with young corn powder. The current outcomes regarding volume of muffins are in agreement with the results reported by Chetana et al. (18), expounded a significant decrease in volume of muffins with increasing levels of raw and roasted flaxseed powder. The volume decreased from 150 cc in control to 120 cc in muffins having 40% roasted flaxseed powder.

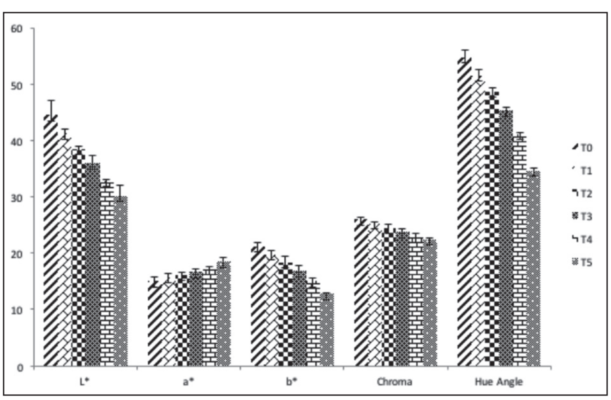

Figure 1. Crust color of protein enriched muffins
T0 = 100% Straight grade flour; T1 = 95% SGF and 5% SPI; T2 = 90% SGF and 10% SPI; T3 = 85% SGFand 15% SPI; T4 = 80% SGF and 20% SPI; T5 = 75% SGF and 25% SPI

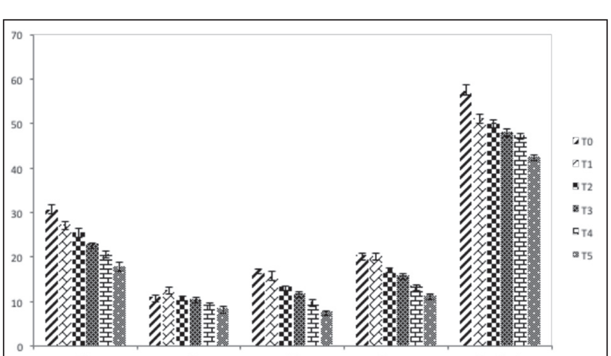

Figure 2. Crumb color of protein enriched muffins

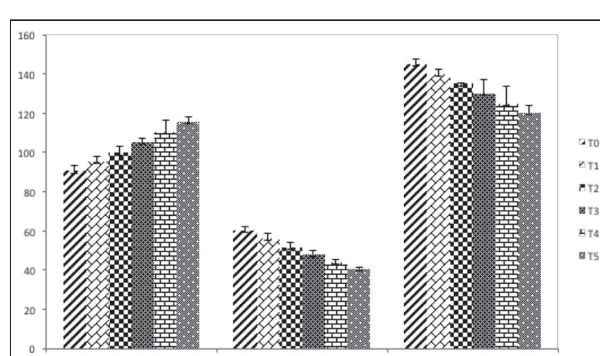

Figure 2. Texture profile and volume of protein enriched muffins

Sensory evaluation of muffins

Sensory evaluation is a pivotal tool to assess the quality attributes of the developed product via opinion of sensory panelists. The prepared muffins were assessed for the treatment effect on color, flavor, texture, taste and overall acceptability and were scored accordingly. The maximum color score 7.50±0.33 was noticed for T_0 (control) while, minimum for T_5 (6.59±0.30) as mentioned in figure 4. The present results elucidated that muffins made by adding 20 and 25% protein isolates were least suitable. A steady decline in color score of muffins was noticed as the quantity of protein isolates increased. This color difference might be attributed to the color and quantity of protein isolates in comparison with straight grade flour (20). Moreover, the color difference may be attributed to moisture absorption from the atmosphere resulting in oxidation. These changes are related with dextrinization of starch and maillard reaction that involves interaction of proteins with reducing sugars (21).

The present results for flavor indicated that the maximum score 7.38±0.28 was exhibited by T_0 trailed by T_3 (7.18±0.11), T_2 (7.14±0.25), T_1 (6.95±0.41) and T_4 (6.69±0.31) whilst, minimum by T_5 (6.46±0.23). The bakery products undergo staling process very quickly that converts rich flavor and aroma of freshly baked product into bland or off flavor (22). Moreover, the oxidation process results in the development of off flavor (23). The sensory results pertaining to taste of muffins indicated that maximum scores were given to T_0 7.36±0.37 followed by T_3, T_2, T_1, T_4 and T_5 as 7.20±0.20, 7.16±0.16, 7.14±0.24, 6.80±0.32 & 6.53±0.27, correspondingly. It is evident from the results that muffins with 15% protein isolates were more liked by the judges whereas further increase in SPI level showed a decreasing trend for flavor scores.

The texture is an imperative quality characteristic of muffins that is related to the freshness of product. Moreover, texture is considered as an indicator of food safety and quality (20). In present research, the maximum scores for texture 7.43±0.16 were exhibited by control (T_0) while, the minimum scores 6.77±0.37 were given to T_5.

The results for overall acceptability (Figure 4) revealed that muffins with higher protein contents were acceptable to the trained taste panelists. Although, the maximum scores were assigned to control (7.37±0.25) but muffins prepared from wheat flour blends with 10 and 15% sesame protein addition were rated higher on hedonic scale. The results were quite conclusive that 15% sesame protein addition received scores of 7.25±0.23 that is in close proximity with control. However, the muffins prepared from flour blends containing 25% same protein isolates rates least (6.55±0.29). Present outcomes are in harmony with the findings of Ramcharitar et al. (24), delineated that flax muffins showed less overall acceptability as compared to control muffins. In another research study conducted by Batool et al. (25), the overall acceptability scores of baked products revealed a decreasing trend with respect to storage time.

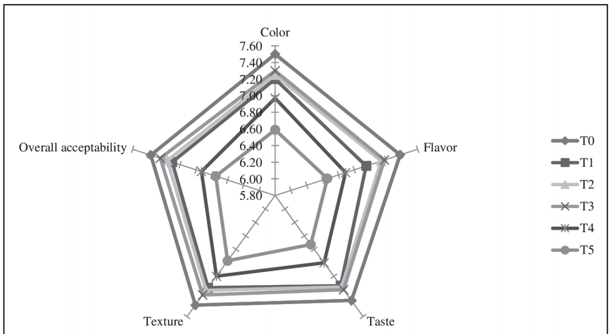

Figure 4. Sensory evaluation of protein enriched muffin

Conclusion

The current exploration indicated that up to 15% addition of sesame protein isolates (SPI) in wheat flour is suitable for the preparation of muffins with no adverse effect on sensory attributes. Conclusively, the protein enriched muffins would provide appreciable quantities of proteins needed by the body to perform its functions. Therefore, muffins can be potentially utilized as a dietary intervention to enhance the nutritional level among masses.

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