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Enhancement the Biological Value of Corn Flakes Using Defatted Sunflower Meal

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Abstract

The challenge encountered by food manufacturers is the enhancement of food quality with essential nutrients and supplementation. The development of a product that is abundant in protein, essential amino acids, and minerals is crucial for enhancing the health of consumers, particularly in foods that are favored by both children and adults. Sunflower protein is emerging as a valuable alternative to animal-based proteins, due to its well-balanced amino acid profile, high digestibility, and versatile application in various food products. Therefore, this study focused on augmenting the nutritional value of corn flakes (100% corn grits) through the fortification with different substitution ratios (15, 30 and 45%) of defatted sunflower meal (DSFM). Approximate analysis of raw materials, changes in pasting behavior and changes in physicochemical properties of final products due to different formulas were estimated. DSFM showed higher protein and minerals (Fe, Zn, P and Ca). Peak viscosity, breakdown and setback viscosity were decreased gradually by increasing level of DSFM. A significant increase in protein, crude fiber, Fe, Zn, P and Ca was proportional to the DSFM level in final products. The control sample showed higher bulk density, lighter color, higher hardness and lower water absorption capacity compared to fortified samples. Fortified flakes recorded higher lysine, phenylalanine, threonine, valine, isoleucine and leucine with higher biological values. No significant differences between the control flakes and other fortified with 15% DSFM regards sensory parameters including taste, crispness, appearance and overall acceptability. It was concluded that, using inexpensive protein could source as DSFM improved the nutritional value of flakes and expand the potential uses for sunflower seed by products.

Keywords: Defatted Sunflower Meal; Corn Grits; Health Benefits; High Protein Flakes

Introduction

Approximately one-third of the world's population suffers from malnutrition, which encompasses individuals experiencing wasting, stunting, and overweight conditions. The Food and Agriculture Organization (FAO) of the United Nations anticipates that by 2030, there will be 600 million individuals facing hunger. The World Health Organization (WHO) estimates that over 2.4 billion people lack consistent access to nutritious food [1]. Populations in low- and middle-income countries predominantly rely on staple foods, such as cereals and starches, which constitute 49% of their diet [2]. Unfortunately, these staple crops often fail to deliver all essential nutrients, thereby heightening the risk of protein deficiency [3]. Plant-derived protein sources frequently exhibit low concentrations of essential amino acids. Insufficient consumption of these essential amino acids, relative to daily needs, serves as a limiting factor that can lead to protein deficiency, ultimately resulting in long-term stunting and wasting. Furthermore, plant-based sources may include components such as anti-nutrients, which can hinder the digestion and absorption of protein [4]. These primary agricultural products may not supply all essential nutrients, thereby heightening the risk of protein deficiency [3]. Protein deficiency significantly contributes to nutritional imbalances and negative health consequences for populations in low- and middle-income countries [4]. Despite previous successful interventions that diminished its prevalence, malnutrition and food insecurity in low- and middle-income countries have seen a resurgence [5]. Malnutrition encompasses under nutrition, micronutrient deficiencies, stunting, wasting, as well as over-nutrition, overweight, and obesity [3]. Due to the high nutritional value of sunflower seeds, they can be used for food fortification, whether defatted sunflower meal [6] or protein extract [7]. Sunflower cake is one of the most important protein foods for livestock feed, especially ruminant nutrition [8]. According to modern nutritional opinion, cereal products such as flakes and snacks are the most common foods in the daily diet. Extrusion technology allows grain-based flake products to be fortified using a variety of raw material sources. The strong antioxidant properties of sunflower meal have a positive impact on human health, therefore, they have attracted the attention of scientists, consumers, and food industry experts [9]. The current work was undertaken to develop low protein flakes (100% corn grits) using DSFM at different substitution levels (15, 30, and 45%) to contribute significantly in fulfilling daily nutritional needs.

Materials and Methods

Materials

Yellow corn was obtained from Egypt Foods Co., Qusena City, Menofya governorate Egypt, sunflower seeds were obtained from oil crops department, ministry of agriculture, Dokky, Egypt, other ingredients including sugar, salt vanilla were obtained from local markets at Giza, Egypt. All chemicals and reagents were of purest quality or analytical grade and bought from, Sigma Aldrich.

Methods

Preparation of raw materials

Corn grits

Corn grits (CG) was based on Suksomboon and Onanong [10] Method, CG were ground intogrits with a particle size 60 mesh. Then stored in PE plastic at room temperature for further processing.

Defatted sunflower meal

Preparation of defatted sunflower meal was prepared by extracting oil from ground sunflower kernels with n-hexane using Soxhlet apparatus. The defatted meal was dried at room temperature and grounded and sieved to 60 mesh particles [11].

Flakes processing

Flakes samples were prepared according to the method described by Leusner[12] with some modifications. Blends (Table 1) were mixed with water until the dough formed (moisture content 22 to 35%); flakes dough that had been formed was then flattened using a roller (thickness 1.0-0.8 mm). After that, it was cut into flakes and dried using an electric oven at 210±2°C for 2-3 min. All obtained flake samples are then stored in plastic bags at room temperature for further analysis.

Table 1: Corn flakes formulation with different replacement ratios of defatted sunflower meal

Ingredients	Corn flakes formulas (g)			
	Control	1	2	3
CG	100	85.00	70.00	55.00
DSFM	-	15.00	30.00	45.00
Salt	0.30	0.30	0.30	0.30
Sugar	2.00	2.00	2.00	2.00
Vanilla powder	2.00	2.00	2.00	2.00

CG= corn grits, DSFM= defatted sunflower meal.

Chemical composition and minerals content

Raw materials and final products were chemically analyzed for moisture, ash according to AACC [13] International methods 44-15.02 (Moisture-Air Oven Method), 08-01.01 (Ash-Basic Method) respectively. Lipids, crude fiber and protein contents were analyzed according to the methods described in AOAC. [14]; Lipids were extracted in soxhlet apparatus using N-hexane as a solvent. Nitrogen free extract (NFE) were calculated by differences.

Pasting properties

The pasting properties of prepared flakes formulas were measured using a rheometer (RheoLab QC, Anton Paar, GmbH, Graz, Austria) in accordance with AACC method 61-02-01 [13].

Amino acids pattern

Amino acids of corn grits and defatted sunflower meal were determined according to the method described in AOAC [14]. Chemical scores were calculated according to FAO/WHO/UNU [15]. Protein Efficiency Ratio (PER) a = 0.456 + 0.454 (Leucine) - 0.047 (pro) and Protein Efficiency Ratio (PER) b = 0.498 + 0.454 (Leucine) - 0.105 (Tyrosine) were calculated [16]. The Biological value (B.V) was assayed according to the following equation which recommended by Eggum et al. [17] by the following equation: B.V.% = 39.55 + 8.89 × lysine (g/100g protein).

Physical properties of flakes

Bulk density (BD) of flakes products was calculated as the ratio of flake mass and cylinder volume [18]. Six samples were used for each flake product to calculate the mean. Bulk density = Weight of flakes (g)/Cylinder volume (cm3). The water absorption capacity was determined as described by Gbadamosiet al. [19].

Texture Properties

The texture characteristics of flake products were determined using a texture analyzer CT3™ (Brookfield) according to modified method (dry cat food P35). Tests were performed by placing 3 flake products from each sample on a flat surface of the device and applying compression using a cylindrical stainless-steel probe with 45 mm diameter at a load cell of 50 kg and a breaking force of 100 g. The hardness of the flakes is defined as the force required to achieve the first fracture of the flakes, read as the maximum value from the obtained curve of force to the probe path dependence (N) [20].

Color Instrumental Analysis

Color parameters of flakes samples were determined in six replications, using Chroma meter (CR-400, Konica, Minolta, Tokyo, Japan) tri-stimulus colorimeter (contact surface diameter: 8 mm). Prior to sample measurements, calibration was performed using the white color standard. Color parameter results were presented according to CIElab color system, where coordinates are defined as follows: L*-brightness (from 0 (black) to 100 (white)), a*—-greenness/redness (from -a* (green) to +a* (red)), b*-blueness/yellowness (from -b* (blue) to +b* (yellow) [21].Browning index was calculated using the following equation:

Browning index= 100(x-0.31)/0.17

where x is (a*+ 1.75L*)/(5.645L*+ a*-0.3012b*) [22].

Organoleptic characteristics

In this study, the test to assess the quality and acceptability was performed according to Kosutić et al. [9] with some modifications by using 10 inexperienced tasters. The tasters were asked to evaluate the following sensory properties of corn flakes with 0, 15, 30 and 45 % of defatted sunflower seeds (DSFS): taste, odor, crispness, color, appearance and overall acceptability using a 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely).

Statistical Analysis

Statistical analysis was performed using SPSS software (version 16) and Duncan's multiple range tests were used for means comparison.

Results and Discussion

Chemical composition and minerals content of used raw materials

The proximal chemical composition of the raw materials is presented in Table 2 and the obtained results showed that corn grits (CG) recorded higher value of moisture content (10.05%) compared to 6.24% that observed by defatted sunflower meal (DSFM). However, DSFM showed the highest values of ash, protein and crude fiber (6.89, 55.00 and 5.65% respectively), in contrast to the highest values of fat content and nitrogen free extract (NFE) were recorded by CG (3.83 and 81.20%, respectively). These results in a harmony with Kadiret al. [23] they found that corn grits contained 11.33% water content, 1.39% ash, 9.40% protein, 3.59% fat, 75.36% carbohydrate content. Also, Mostafa et al. [24] reported that corn flour contained 9.76% protein, 2.94% crude fiber and 81.79% NFE, others, Helmyet al. [25] reported that corn grits contained 8.35% protein, 5.20% fat and 72.905 total carbohydrates.

Table 2: Chemical composition of raw materials (corn grits and defatted sunflower meal)

Approximate analysis (d.w.b)	Raw materials	
	Corn grits	Defatted sunflower meal
Moisture (%)	10.05	6.24
Ash (%)	2.51	6.98
Fat (%)	3.83	1.56
Protein (%)	9.85	55.0
Crude fiber (%)	2.61	5.65
NFE (%)	81.20	30.81
Iron (mg/100g)	2.43	6.05
Zinc (mg/100g)	1.57	4.98
Phosphorus (mg/100g)	219.30	704.90
Calcium (mg/100g)	11.94	630.00

NFE= nitrogen free extract

On the other hand, Vasudha and Sarla [26]studied the chemical gross of sunflower seed cake and they stated that it contained 37.10% protein, 0.69% fat and 7.49% ash. Also, the approximate composition of defatted sunflower seeds was determined by Grasso et al. [27]and they mentioned that contained 38,01% protein, 1.84% fat and 7.19%

ash. Also, the mineral content of corn grits (CG) and defatted sunflower meal (DSFM) were estimated including iron, zinc, phosphorus and calcium and the obtained data indicated that DSFM showed higher values of all determined minerals (6.05, 4.98, 704.90 and 630.00, respectively) compared to the lower values which observed the corn grits. Muttagi and Joshi [28] studied the minerals composition of selected sunflower seed cultivars and they found the phosphorus content ranged between (640 to 670.49 mg/100), iron (4.67 to 4.76 mg/100g) and zinc (3.77 to 4.05 mg/100g). While, Petraru et al. [29] stated that sunflower seed contained 5.78 mg/100g zinc. calcium content of 10.15-10.92 mg/100g [23].

Effect of replacement of corn grits by different ratios of defatted sunflower meal on pasting properties of mixture blends

Pasting properties have proven to be a valuable tool in assessing the cooking level of cereal-based products. This method is among the various techniques used to study the state of starch in complex formulated products [30]. it becomes feasible to accurately quantify the changes that occur in starch during thermal or thermo-mechanical processing [31]. Therefore, pasting behavior of corn grits and other blends contained 15, 30 and 45% of defatted sunflower meal were conducted and the obtained data are presented in Table 3 and illustrated in Figures 1. The obtained results indicated that, corn grits recorded the highest values of peak viscosity (3610 cP) and final viscosity (4610 cP), where the same aforementioned parameters were gradually decreased with the increasing level of DSFM in prepared formulas, consequently, the lowest values of peak viscosity and final viscosity were observed by the sample consists from 55% corn grits with 45% defatted sunflower meal. The rise in viscosity of corn grits could potentially be attributed to the expansion of starch granules, which might have been hindered by the existence of the protein network [32].

Table 3: Pasting properties of mixture blends

Pasting behavior	Samples			
	Control	1	2	3
Peak Viscosity (cP)	3610.00	2579.0	2093.0	1410.0
Pasting Temperature (°C)	62.3	62.9	68.7	69.4
Peak Temperature (°C)	94.7	94.6	94.8	95.0
Holding Strength (cP)	2429.0	1724.0	1536.0	1071.0
Breakdown (cP)	1181.0	873.7	557.5	339.0
Final Viscosity (cP)	5791.0	4789.0	3701.0	2152.0
Setback from Trough (cP)	4610.0	3915.0	3143.0	1813.0

Control= 100% corn grits, 1= 85% corn grits + 15% defatted sunflower meal, 2= 70% corn grits + 30% defatted sunflower meal, 3= 55% corn grits + 45% defatted sunflower meal

Concerning the pasting temperature, a slight increase was observed between the sample contained 15% DSFM and control sample (62.90 and 62.30 °C, respectively), while the highest values of pasting temperature (68.70 and 69.40,°C) were recorded by the sample contained 30% DSFM and other contained 45% DSFM, respectively. On other side, the holding strength, breakdown and setback were deceased with the increasing replacement levels of corn grits by defatted sunflower meal. The dissimilarities observed can be ascribed to the extent of amylose lixiviation. The starch particles that undergo less conversion have the ability to release amylose, which then undergoes retrogradation and leads to an increase in the setback viscosity. Conversely, the presence of insoluble fiber in the extruded flour impedes amylose retrogradation and results in a decrease in the setback viscosity [33].

Effect of replacement of corn grits by different ratios of defatted sunflower meal on nutritional quality of flakes

The approximate chemical composition of flakes samples was determined and the obtained data are presented in Table 4. From the obtained results, it can be seen that, the control sample (100% corn grits) significantly ($P \leq 0.05$) recorded the lowest value of moisture content (2.98%). The findings also indicated the ash, protein and fiber content of fortified flakes were gradually increase with the increasing level of defatted sunflower meal (DSFM), where the fortified sample (15% DSFM) significantly achieved a relative increase of ash, protein and fiber (13.06%, 92.44% and 14.64%, respectively).

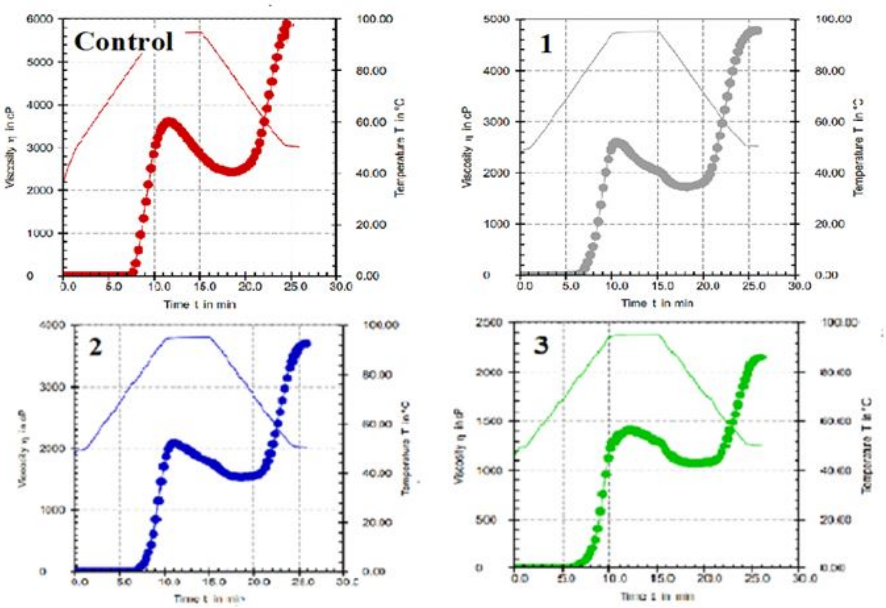

Figure 1: Pasting properties of flakes formulas, control= 100% corn grits, 1= 85% corn grits + 15% defatted sunflower meal, 2= 70% corn grits + 30% defatted sunflower meal, 3= 55% corn grits + 45% defatted sunflower meal.

Table 4: Chemical composition and minerals content of prepared flakes

Approximate analysis (d.w.b)	Raw materials				LSD at 0.05
	Control	1	2	3	
Moisture (%)	2.98d	3.20c	3.45b	3.78a	0.197
Ash (%)	2.45c	2.77c	3.52b	4.28a	0.443
Fat (%)	3.75a	3.48ab	3.12bc	2.76c	0.476
Protein (%)	8.47d	16.30c	23.18b	29.59a	1.098
Crude fiber (%)	2.55d	3.00c	3.47b	3.89a	0.410
NFE (%)	82.78a	74.45b	66.71c	59.48d	3.557
Iron (mg/100g)	2.16d	3.06c	3.61b	4.15a	0.336
Zinc (mg/100g)	1.38d	2.14c	2.69b	3.31a	0.385
Phosphorus (mg/100g)	210.08d	303.54c	368.75b	450.71a	34.700
Calcium (mg/100g)	11.06d	113.17c	205.59b	306.52a	33.321

Means in the same row with different letters are significantly different ($P<0.05$).

While the sample contained 30% of DSFM significantly achieved relative increase 43.67%, 144.77% and 36.07%, respectively, in the same way, the fakes sample contained 45% DSFM achieved by 71.76%, 212.45% and 52.54% for the same aforementioned parameters respectively with significant differences.

Accordingly, the control flakes sample showed the highest value of NFE (82.78%) with significant differences compared to the lowest value (59.48%) which recorded by the sample contained 45% DSFM. Medina et al. [34]studied the approximate analysis of control flakes (100% corn grits) and reported that contained 6.27% protein, 2.09% ash and 91.43% total carbohydrate contents. While, these results are in line with those of Dewidar and EL ghandour [35], they suggested that cornflakes (100% yellow corn) contained 7.54% protein, 2.57% crude fiber and 3.73% fat content.

Regards the effect of replacement of corn grits (CG) by of defatted sunflower meal (DSFM) at different ratios (15,30 and 45%) on minerals content of prepared flakes and from the result it can be noticed that, the control sample (100% corn grits) recorded the lowest values of iron, zinc, phosphorus and calcium with significant differences compared to other fortified flakes, where the replacing corn grits with different levels of DSFM (15,30 and 45%) led to a significant increase in minerals content (Fe, Zn, P and Ca) in direct proportion to the percentage of DSFM. It is worth noting that the percentage of iron in the fortified samples ranged between 3.06 to 4.15% compared to 2.16% which investigated by the control sample with significant differences. According to Dewidar and EL ghandour [35], the control corn flakes (100% yellow corn) contained 227.89 mg/100g phosphorus, 3.29 mg/100g iron and 1.48 mg/100g zinc.

Effect of replacement of corn grits by different ratios of defatted sunflower meal on physical properties of flakes

Bulk density (BD), color values and water absorption capacity of flakes for control sample (100% corn grits) compared to other samples which corn grits was replaced with 15, 30 and 45% of defatted sunflower meal (Table 5).The property of bulk density signifies the alteration and enlargement in the structure of cells and according to the obtained data the highest value of BD (0.44 g/cm3) was recorded by the control sample (100% corn grits) with significant differences (P≤0.05) compared to all fortified samples except the sample contained 15% DSFM.

Table 5: Physical properties of flakes

Physical parameters	Flakes samples				LSD at 0.05
	Control	1	2	3	
Bulk density (g/ cm3)	0.44a	0.40ab	0.37bc	0.33c	0.052
L*	63.14a	57.97b	53.29c	48.20d	4.452
a*	8.80a	6.84b	4.92c	2.16d	0.365
b*	25.47a	22.10b	17.61c	13.30d	3.352
Browning index	7.45a	6.11b	4.44c	2.85d	0.377
WAC at 30 °C (g/g)	18.66c	20.53c	24.87b	29.71a	2.260
WAC at 50 °C (g/g)	54.74c	59.29b	64.99a	67.74a	3.122
WAC at 70 °C (g/g)	66.15d	70.65c	76.64b	81.97a	1.749

Means in the same row with different letters are significantly different (P<0.05). control= 100% corn grits, 1= 85% corn grits + 15% defatted sunflower meal, 2= 70% corn grits + 30% defatted sunflower meal, 3= 55% corn grits + 45% defatted sunflower meal.

Figure 2: Photographs of prepared flakes, control= 100% corn grits, 1= 85% corn grits + 15% defatted sunflower meal, 2= 70% corn grits + 30% defatted sunflower meal, 3= 55% corn grits + 45% defatted sunflower meal.

Concerning the color values (illustrated in Figure 2), the highest value of L* parameter (63.14) significantly recorded by the control sample (more lightness), consequently, a gradual decrease was observed in lightness values (L*) in a direct proportional with the increment of DSFM levels.

The same tends also were observed in terms of redness and yellowness values (a* and b*, respectively), where the highest values of the same aforementioned parameters (8.80 and 25.47, respectively) were recorded by the control sample with significant differences, on the contrary, the lowest values (2.16 and 13.30, respectively) significantly recorded by the sample contained 45% of DSFM. Helmy et al. [25] studied the effect the color values of prepared corn flakes and they found that it ranged from 45.68 to 72.35for lightness, 8.33 to 10.21for redness and 13.42 to 20.76 for yellowness values. While Fasuan et al. [36]studied the effect of high protein soymeal addition to corn flakes formula on color parameters which results in lower L*, a* and b* values (55.42, 2.51 and 4.05, respectively).This, despite the high protein content of DSFM fortified samples, there is a significant decrease in the brown index, and this is due to the degree of the sunflower color that tends towards green color, which in turn leads to a decrease in the a* value in the fortified samples and reduces the effect of the Maillard reaction towards a high value of brown index.

The water absorption capacity (WAC) of the prepared flakes was estimated at 30 °C, 50 °C and 70 °C. According to the statistical analysis, the control flakes (100% corn grits) recorded lower WAC at 30 °C, 50 °C and 70 °C with significant differences compared to other fortified samples except the sample contained 15% DSFM at 30°C, Generally, the data showed that as the temperature increased, the WAC of the flakes increased. The same results were observed by Fasuan et al. [36], they stated that higher protein flakes recorded higher AWC values which increased as the temperature values were increased.

Effect of replacement of corn grits by different ratios of defatted sunflower meal on texture quality of flakes

The flake products' textural attributes play a crucial role in determining consumer satisfaction [9]. The texture parameters that analyzed in these flakes products are the hardness values that indicate the crispness of flakes products which produced in this study. The results of the analysis of the hardness of flakes are shown in Figure 3. According to the obtained data the highest value for hardness (29.68 N) was observed in control sample (100% corn grits). On the other hand, the replacement of corn grits with different levels of defatted sunflower meal (DSFM) led to decrease the hardness of final product, where the degree of hardness was in inverse proportion to the increase in the percentage of replacing corn grits with DSFM. These results are in accordance with the data reported by Anton et al., [37] and Kosutić et al., [9] they concluded that texture properties that are highly influenced by the expansion ratio had lower hardness.

Effect of replacement of corn grits by different ratios of defatted sunflower meal on amino acids content and protein quality of prepared flakes

A comparison between the control flakes (100% corn grits) and other flakes containing different ratios of defatted sunflower meal (15, 30 and 45%) in terms of amino acid content and protein quality are presented in Tables 6, 7 and 8.

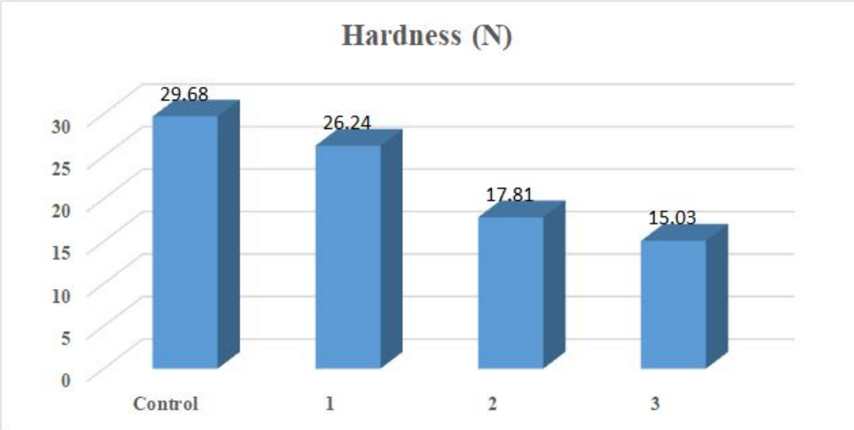

Figure 3: hardness of prepared flakes

Where: control= 100% corn grits, 1= 85% corn grits + 15% defatted sunflower meal, 2= 70% corn grits + 30% defatted sunflower meal, 3= 55% corn grits + 45% defatted sunflower meal

Table 6: Amino acids content of prepared flakes

Amino acids	Amino acids content of raw materials (g/100g protein)			
	Control	1	2	3
Essential amino acids (EAA)				
Lysine	2.24	3.07	3.87	4.8
Cysteine	1.05	0.27	0.19	0.12
Methionine	2.73	2.4	2.1	1.58
Phenylalanine	2.47	2.82	3.16	4.31
Threonine	10.09	10.74	11.48	12.13
Valine	4.06	5.33	7.6	9.27
Tyrosine	2.3	2.57	2.82	3.08
Isoleucine	4.45	4.71	5.36	5.94
Leucine	8.07	8.26	8.65	9.04
Histidine	3.34	3.74	4.15	5.25
Total EAA	40.80	43.91	49.38	55.52
Non-essential amino acids (NEAA)				
Proline	3.66	3.15	2.65	2.14
Arginine	7.64	6.22	4.81	3.39
Serine	13.19	10.37	7.54	4.72
Glutamic acid	9.93	10.39	10.85	11.31
Glycine	5.19	5.40	5.60	5.79
Alanine	3.14	2.40	1.66	0.92

Aspartic acid	5.03	7.10	9.18	11.25
Total NEAA	47.78	45.03	42.29	39.52

control= 100% corn grits, 1= 85% corn grits + 15% defatted sunflower meal, 2= 70% corn grits + 30% defatted sunflower meal, 3= 55% corn grits + 45% defatted sunflower meal.

Table 7: The chemical scores of prepared flakes compared with the required pattern control recommended by FAO/WHO/UNU (1985)

Amino acids	FAO/WHO/UNU (1985) pattern	Amino acids score for prepared flakes			
		Control	1	2	3
Lysine	5.80	0.39*	0.53*	0.67*	0.83**
Methionine + Cysteine	2.50	1.51	1.07***	0.92**	0.68*
Phenylalanine + Tyrosine	6.30	0.76**	0.86**	0.95***	1.17***
Threonine	3.40	2.97	3.16	3.38	3.57
Valine	3.50	1.16***	1.52	2.17	2.65
Isoleucine	2.80	1.59	1.68	1.91	2.12
Leucine	6.60	1.22	1.25	1.31	1.37
Histidine	1.90	1.76	1.97	2.18	2.76

Chemical score was calculated as a percentage of the FAO/WHO/UNU (1985) indispensable amino acid*: First limiting amino acid**: Second limiting amino acid. ***: Third limiting amino acid.

Table 8: Protein quality of prepared flakes

Protein quality parameters	Amino acids score for prepared flakes			
	Control	1	2	3
Protein Efficiency Ratio (PER)a	3.95	4.06	4.26	4.46
Protein Efficiency Ratio (PER)b	3.92	3.98	4.13	4.28
Biological value% (B.V)	59.46	66.84	73.95	82.22

As presentment in Table 6, the obtained results offered that the replacement of corn grits (CG) by varying levels of DSFM led to increase lysine content of prepared flakes which in the same line with the results obtained by Kosutić et al. [38], they stated that addition of sunflower 6 and 9 % in corn flakes contributed to statistically significant increase in lysine as essential amino acid. Silva et al. [39] recommend using sunflower meal as a partial substitute for soymeal, which is low in lysine content. Also, the replacement of CG by different ratios of DSFM showed a positive concerning the increasing levels of other essential amino acids (EAA)including phenylalanine, threonine, tyrosine, isoleucine, leucine, valine and histidine. Noting that, the lowest value of total EAA (40.80%) was obtained by the control flakes which arrived to 55.52 % with 45% replacement level of DSFM. The obtained data also in agreement with Kosutićet al. [38], they mentioned that the addition of sunflower (3, 6 or 9 %) contributes to a statistically significant higher values of threonine and histidine content in comparison with samples without sunflower addition. As for non-essential amino acids (NEAA) the control flakes recorded higher values for proline, arginine, serine and alanine compared to other samples which contained different replacement ratios of DSFM. Consequently, the highest value of total NEAA (47.78%) was observed by the control sample. Thus, the first, second and third limiting amino acids of control flakes and other DSFM-substituted flakes (Table 7) were calculated and the obtained data showed that lysine is the first limit amino acid in control sample and DSFM-substituted samples (15 and 30%), while the slightly increasing level of lysine due to DSFM led to make it the second limited amino acids with 45% DSFM replacement level. Conversely, sulfuramino acids (Methionine + Cysteine) gradually decreased with the increasing level of DSFM to be the first limited amino acids in flakes sample that contained the highest substitution level of DSFM (45%). Meanwhile, valine showed a clear increase with all DSFM-substituted samples compared to the control sample that showed valine as the first limited amino acid. On the other side, a gradual increase in protein quality (PERa,b and biological value) was found to be directly proportional to the increase in DSFM ratios (Table 8).Generally, the fortification process resulted in a more balanced amino acid profile when compared to the control, which consisted solely of corn grits, where, the quality of the corn grits is subpar due to the insufficient levels of two essential amino acids, tryptophan and lysine, alongside an excessive concentration of leucine, leading to an amino acid imbalance [40]. These results also in a harmony with other previous study [41] regarding methionine as a limiting amino acid in DSFM.

Table 9 showed the sensory parameters of prepared flakes replaced with different levels of DSFM (15, 30 and 45%) compared to the control sample (100% corn grits). According to the statistical analysis (P≤0.05), no significant differences between the control sample and others contained 15, 30 and 45% DSFM concerning the taste parameter, meanwhile the sample contained 30% DSFM recorded the highest score (7.80) with significant differences compared to the lowest value (7.20) which investigated by the sample contained 45% DSFM, this can be explained descriptively, as all samples are ranked like moderately regards the taste parameter for all flakes samples. On the other hand, the replacement of CG by DSFM (15,30 and 45%) had a negative effect on the odor parameter of the final product where the highest score (8.40) significantly recorded by the control sample.

Table 9: Organoleptic characteristics of prepared flakes

Sensory parameters	Samples				LSD at 0.05
	Control	1	2	3	
Taste (9)	7.40ab	7.60ab	7.80a	7.20b	0.567
Odor (9)	8.40a	7.80b	7.60b	7.40b	0.595
Color (9)	8.40a	8.20ab	7.80b	6.80c	0.538
Crispness (9)	8.60a	8.40a	7.81b	7.20c	0.568
Appearance (9)	8.60a	8.40a	8.00ab	7.60b	0.671
Overall acceptability (9)	8.40a	8.00ab	7.40bc	7.20c	0.647

Means in the same row with different letters are significantly different (P<0.05). Control= 100% corn grits, 1= 85% corn grits + 15% defatted sunflower meal, 2= 70% corn grits + 30% defatted sunflower meal, 3= 55% corn grits + 45% defatted sunflower meal.

Descriptively, only the control sample is described as like very much, except for the other fortified flakes are described as like moderately. The color and crispness parameters also were negatively affected by higher replacement ratios of DSFM, where no significant differences between the control and the samples contained 15% DSFM regards the same aforementioned parameters and were found to described as like very much, while the color and crispness scores were decreased with the increment of DSFM ratios, where the sample contained 30% of DSFM recorded lower scores in terms of color (7.80) and crispness(7.81) with significant differences and described as like moderately.

Statistically, no significant differences between the control sample and other flakes contained 15 and 30% DSFM concerning the appearance parameter and all of which are described as like very much. As for the overall acceptability, the highest scores (8.40 and 8.00) were obtained by the control sample and other contained 15% DSFM respectively with no significant between them and with significant differences compared to other fortified samples.

Conclusion

This article investigated the enhancement of corn flakes through the incorporation of different substitution levels of defatted sunflower meal, utilized as a natural protein source. The impact of replacing corn flour with 0%, 15%, 30%, and 45% defatted sunflower meal on the chemical, physical (color and textural profile) and organoleptic of flakes was also investigated. The defatted sunflower meal contained a good amount of essential amino acids and nonessential amino acids. Including defatted sunflower meal in flakes improved the nutritional value regarding protein content with only slightly reduced quality. The nutritional, rheological, color and textural results of the present work show the potential of employing defatted sunflower meal as a nourishing ingredient to make flakes of high quality. The overall acceptability score indicated that pasta enhanced with 15% and 30% defatted sunflower meal were satisfactory to the judges, and there was no substantial difference in taste and texture compared with the control. These results are valuable because they demonstrate how adding inexpensive protein could raise the nutritional value of flakes and expand the potential uses for sunflower seed by products.

Data Availability Statement

All datasets generated or analyzed during this study are included in the manuscript.

Ethics Approval

Not applicable.

Informed Consent

Not applicable.

Consent for Publication

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

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