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Original Article

Physicochemical, Functional, Long Chain Fatty Acids, and Sensory properties of Walnut Processed Cheese

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ABSTRACT

This study developed and characterized pasteurized processed cheese enriched with walnut paste, a valuable source of essential fatty acids, including omega-3. To determine the optimal formulation, various walnut paste concentrations (0%, 10%, 20%, and 30%) were evaluated for their effects on physicochemical properties, long-chain fatty acid profile, functional characteristics, and sensory attributes. Results demonstrated that walnut paste supplementation significantly increased fatty acid content (MUFAs: Oleic acid; PUFAs: Linoleic acid(omega-6) and Linolenic acids(omega-3)), elevated acidity, reduced protein and ash content, and enhanced oil separation index and meltability compared to the control ($p \leq 0.05$). The 20% walnut paste formulation exhibited the most favorable sensory properties, achieving the highest scores in flavor and color acceptance. These findings indicate that walnut paste incorporation serves as an effective nutritional strategy to enhance health-promoting fatty acids in processed cheese while maintaining desirable sensory and technological qualities.

Keywords: Processed cheese, walnuts, Pesta cheese, essential fatty acids, GC-MS.

1 Introduction

Processed cheese is recognized as a widely consumed dairy product, with recent innovations leading to specialized varieties [1]. Typically manufactured from natural cheese combined with unfermented dairy ingredients, emulsifiers, and various additives, processed cheese offers diverse flavors, colors, and textures [2]. Historical records indicate that while Walter Gerber of Thun, Switzerland first developed processed cheese in 1911, James L. Kraft secured the initial American patent in 1916. Although valued for convenience and extended shelf life, processed cheese generally exhibits lower nutritional quality compared to natural cheese, characterized by higher sodium and fat content alongside reduced vitamin and mineral concentrations [3]. Growing consumer demand for healthier food options has stimulated interest in enhancing the nutritional profile of processed cheese [4]. Contemporary food technological approaches focus on incorporating functional ingredients such as nuts, fruits, vegetables, herbs, and spices into cheese formulations [5]. Walnut paste, known for its high levels of omega-3 fatty acids, antioxidants, and polyphenols, offers substantial health benefits, while whey protein provides high-quality protein that improves texture and emulsification properties [6]. El-Neshawy et al [7] produced processed cheese food with a high protein ratio using a mixture of Cheddar cheese, chickpea flour, soybean protein concentrate (SPC) and whey protein concentrate (WPC). Whey and whey products have been used successfully in spreads cheese, cold pack "club" cheese foods and pasteurized processed cheese foods/spreads for years. Sweet whey, whey protein concentrates 34-80% protein (WPC), modified whey, reduced-lactose whey, demineralized whey and whey protein isolates (>90% protein, WPI) are among the most commonly used whey products [8]. Pesta cheese is ripened and one of the most popular cheeses, in the Kurdistan region of Iraq and other Kurdish regions in Iran, Syria and Turkey, has a special sharp flavor, produced from cow, goat, or sheep's milk by the nomadic and villagers' people, consumed widely in the northern region of Iraq [9]. Using ripened cheese to produce processed cheese are according to the kind, age, and characteristic of the natural cheese have mainly role in controlling the sensorial properties, textural, viscoelastic, functional, and microstructural of process cheese [10]. This study explores the effects of incorporating Pesta cheese and fortifying processed cheese with different ratios of walnut paste and whey protein. The current investigation examines the effects of incorporating Pesta cheese and fortifying processed cheese with varying walnut paste and whey protein ratios, analyzing impacts

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on physicochemical and functional properties, texture, and long-chain fatty acid composition to develop nutritionally enhanced functional processed cheese with improved sensory characteristics.

2 Materials and Methods

2. 1 Materials

A 2000 g of the local Pesta cheese ripened for six months content of 33.47% fat, 26.41% protein, 38.25 % moisture and 5.22% ash, mixed with 2000g of the white soft cheese content of 35.59%fat, 11.13 %protein, 48.18% moisture and 3.12%ash, cut into small cube to produce of pasteurized processed cheese, while sweet whey remained from producing of soft cheese, instead of water were used to produce a process cheese A 1000g of roasted walnuts (*Juglans regia*) component of (61.13% fat, 15% protein, 3.11% moisture, 0.75% ash and 42.99 mg/g total phenolic) were treated completely for 2 minutes by using the food electric grinder to obtain walnuts paste and heated it at 150 ˚C/ 20 min in oven, tri-sodium citrate dihydrate (Sigmaaldrich Co. /Germany) were used to prepare of processed cheese

2. 2 Methods

2. 2. 1 Formulation of the different Walnuts Process Cheese treatments

Different percent of walnuts paste(0,10, 20,30)% were used to make four different formulations of walnut processed cheese by using 50% white soft cheese and 50% local Pesta cheese as base raw material according to Food and Drug Administration [11], then mixed, 10-20% whey protein, 3% of emulsifying salt (Tri-sodium citrate hydrated, after that cooked by mixing machine (Stephan Machinery Co., New York, NY, USA) at 80-85˚C for 6 minutes with mixing, the speed was 3000 rpm with selection of cooling temperature 50 °C to produce molten cheese mass, the production of process cheese was according to Rafiq and Ghosh [12], then filled in small glasses containers(200g), stored at 5-7 ˚C to make the specific analysis administrated.

2. 2. 2 Physicochemical and Functional Characteristics Analysis

Each of protein, ash, moisture, titratable acidity and pH of the process cheese were measured according to AOAC methods in triplicate samples for each one analysis [13]. Lipid content analysis employed using the Soxhlet extraction method with hexane as the nonpolar solvent [14]. Meltability was assessed through the Schreiber test with modifications: cheese samples were formed into discs (4 cm diameter, 10 mm thickness), heated at 110°C for 10 minutes, and meltability percentage calculated using the formula: [(melted disc area - original disc area)/original disc area] × 100 [15].

Oil separation index was measured according to Thomas [16], three samples of each cheese treatments puts as a disc in the Whatman No.41 filter paper, put in oven at 110 ˚C for 10 minutes, the ring of fat was indicator to the fat soaks of the melted cheese, the equation in the followed down was used to measured oil separation index (the area of fat ring and disc–the area of original disc)/the area of original *100.

2. 2. 3 Determination of long chain fatty acids for processed cheese by Gas chromatography-Mass Spectrometry (GC-MS)

One microliter of the sample was injected, at a 260°C injector temperature in a flow rate of 1 ml/minute. The column used was an HP-5 MS and the length was 30 meters with a diameter of 0.25 mm. The run program included 60 °C for 4 min, then 3 °C/min to 100 °C for 2 min, then 4 °C/min to 260 °C for 5 min [17]. The data was analyzed in a chemical laboratory (photon center)/Baghdad, and long chain fatty acids were identified, quantified, and exported as clear in the results.

2. 2. 4 Sensory Evaluation

The product was evaluated by ten panelists. The sensory characteristics of cheese samples (taste, texture, appearance, smell, and overall acceptability) at room temperature, the evaluation was performed after 24 hours of production of processed cheese using nine score of grading on which 1 referred (high quality) and 9 referred (bad quality) [18].

2. 2. 5. Statistical Analysis

One-way statistically analysis of variance ANOVA by LSD test ($p \leq 0.05$) was used to evaluated the difference among the mean values for data of physicochemical characteristics, functional properties, main long chain fatty acids content and sensorial analysis of pasteurized processed cheese, Principal Component Analysis(PCA) was performed on fatty acid, physicochemical, functional data and sensory analysis the analyses were carried out in triplicate, obtained results were expressed as mean values ± standard deviation.

3 Results

3. 1 Physicochemical and Functional properties of the walnut process cheese

Table1.illustrate the characteristics of the physicochemical and functional properties of the walnuts process cheese. Accordingly, Fat content demonstrated a concentration-dependent increase with rising walnut paste supplementation, progressing from 19.8% in the control to 23.1%, 27.0%, and 28.8% in 10%, 20%, and 30% walnut paste treatments, respectively. So significant differences were found between the control treatment and other walnuts processed cheese treatments at ($P \leq 0.05$). The content of the moisture in the walnuts process cheese samples was lower than control sample, as well as protein, ash, and NaCl content in process cheese containing walnuts was lower than the control sample, The addition of walnuts in pasteurized process cheese caused a decrease in pH and an increase in % acidity than the control sample. By increasing walnuts addition to process cheeses the acidity had been increased. All attributes showed statistically significant differences ($P \leq 0.05$) among treatments.

3. 2 Meltability and Oil Separation

In the type of processed cheese, meltability is one of the most important functional properties. As appears in Table 1, there were differences in each of meltability and oil separation between the control treatment and the treatments of walnut process cheese, noticed, the meltability of cheese containing walnuts increased by increasing the walnuts ratio. Compared with the control, the meltability of cheeses containing walnuts was higher, which means that were easily melted. About the oil separation index of process cheese treatments, information in Table1 indicated that control cheese (75.6) did not differ significantly with 10% and 30% walnuts process cheese that were (75.5, 76.74) respectively, but had a lower value compared to processed cheese with 20% walnut paste, which had the highest 85.71. The oil separation index gradually increased within increasing the level of walnuts, 10% walnuts processed cheese was the best one to the oil separation index.

Table 1: Physicochemical and functional properties of Walnuts process cheese with different ratio of walnuts (10, 20 and 30) % walnuts paste.

Parameters	**Walnuts process Cheese**			
	0% Walnuts (Control)	**10% Walnuts**	**20 % Walnuts**	**30 % Walnuts**
Fat %	19.8±0.10 d	23.1±0.07 c	27.0 ±0.01 b	28.8 ±0.06 a
Protein %	31.4 ±0.01 a	21.1 ±0.00 b	18.9±0.21 c	18.3±0.21 c
Moisture %	51.8 ±0.11 a	39.6 ±0.01 b	38.6 ±0.00 b	35.4 ±0.41 c
Ash %	3.82 ±0.31 b	3.98 ±0.05 a	3.14±0.05 c	2.95±0.09 d
NaCl	1.0±0.08 d	2.15 ±0.01 c	2.47±0.11 b	2.96 ±0.00 a
Acidity %	1.29 ±0.01 d	1.50 ±0.51 c	1.95 ±0.09 b	2.04±0.03 a
pH	6.29±0.20 a	5.72±0.00 b	5.88±0.33 b	5.98 ±0.00 b
Meltability %	12.5 ±1.01 c	5.2±2.21 d	45.9 ±2.01 b	45.97 ±2.54 a
Oil separation index %	75.6±0.00 b	75.5±0.11 b	85.7 ±0.01 a	76.74±0.08 b

The results were expressed as mean SD; means with different coordinating in a row differ significantly ($p \leq 0.05$).

3. 3 Long chain fatty acids of Walnuts Processed Cheeses

The effect and benefit of walnuts paste addition on the fatty acids composition of walnuts process cheeses is dispense in table 2, shows the contents of eight the long chain fatty acids, include three unsaturated fatty acids (USFA) and five saturated fatty acids (SFA), in mg/kg under four treatments of process cheese (Control, 10%, 20%, and 30%) for each of fatty acids (oleic acid(C18:1), linoleic acid(C18:2), and Linolenic (C18:3), Myristic acid(C14:0), Palmitic acid(C16:0), Stearic acid(C18:0), Arachidic acid(C20:0), and Lignocericacid(C24:0)), The peaks of long-chain fatty acids present in walnut-processed cheese treatments and their quantities were illustrated in figure (1). Data analysis revealed that all unsaturated fatty acids (USFA) (C18:1, C18:2, C18:2) increased progressively with increase walnuts paste contents in treatments, and had different significantly at ($P \leq 0.05$) with control treatment. While linoleic acid (C18:2) shows the strongest increase: from ~6818 mg/kg in control treatment to ~15058 mg/kg at 30% walnuts paste processed cheese.

Table 2: The main long chain fatty acids of Walnuts Process Cheeses containing (0,10, 20 and 30)% walnut paste

Fatty acids	**Treatments**				Treatments
	0% Walnuts (Control)	**10% Walnuts**	**20 % Walnuts**	**30 % Walnuts**	
Unsaturated fatty acids (USFA mg/kg)					
Oleic acid(C18:1)	2907.18 ±0.43 a	3856.23 ±0.31 b	4979.48 ±0.00 c	5136.56 ±0.21 d	
Linoleic acid(C18:2)	6818.1±0.06 a	8018.22±0.41 b	13639.15±0.01 c	15057.97 ±0.03 d	
Linolenic acid(C18:3)	2114.45±0.0 a	3186.26 ±0.00 b	4611.25 ±0.04 c	5333.6±0.04 d	
Saturated fatty acids (SFA mg/kg)					
Myristic acid(C14:0)	103507.7±0.05 a	109215.25 ±0.05 b	162044.43±0.03 c	180961.01±0.00 d	
Palmitic acid(C16:0)	5005.4±0.02 a	6151.52±0.09 b	8514.79±0.31 c	9012.07±0.01 d	
Stearic acid(C18:0)	1712.68±0.41 a	1951.22±0.33 b	2876.94 ±0.11 c	3005.33±0.01 d	
Arachidic acid(C20:0)	1941.41 ±0.00 a	2026.57 ±0.31 b	2910.84±0.19 c	3014.48±0.00 d	
Lignoceric acid(C24:0)	2933.25±0.61 a	3269.47±0.01 b	5067.54±0.01 c	5316.64 ±0.09 d	

The results were expressed as mean SD; means with different coordinating in a row differ significantly ($p \leq 0.05$).

Total UFAs in cheese accounted for about (15060.71, 23229.88, 25528.13) mg/kg in treatments containing walnut paste (10, 20, 30) %, respectively compared to the control treatment, which was contained approximately 11839.73 mg/kg. Also, all saturated fatty acids increase with walnut paste supplementation. Myristic acid (C14:0) shows an extremely high concentration compared to

other fatty acids (over 100000mg/kg), and it keeps rising as walnut paste increases. Palmitic, stearic, arachidic, and lignoceric acids also increases with walnut addition but remain much lower than myristic acid. Walnut supplementation boosts both USFAs and SFAs, but the proportional increase is stronger for unsaturated fatty acids.

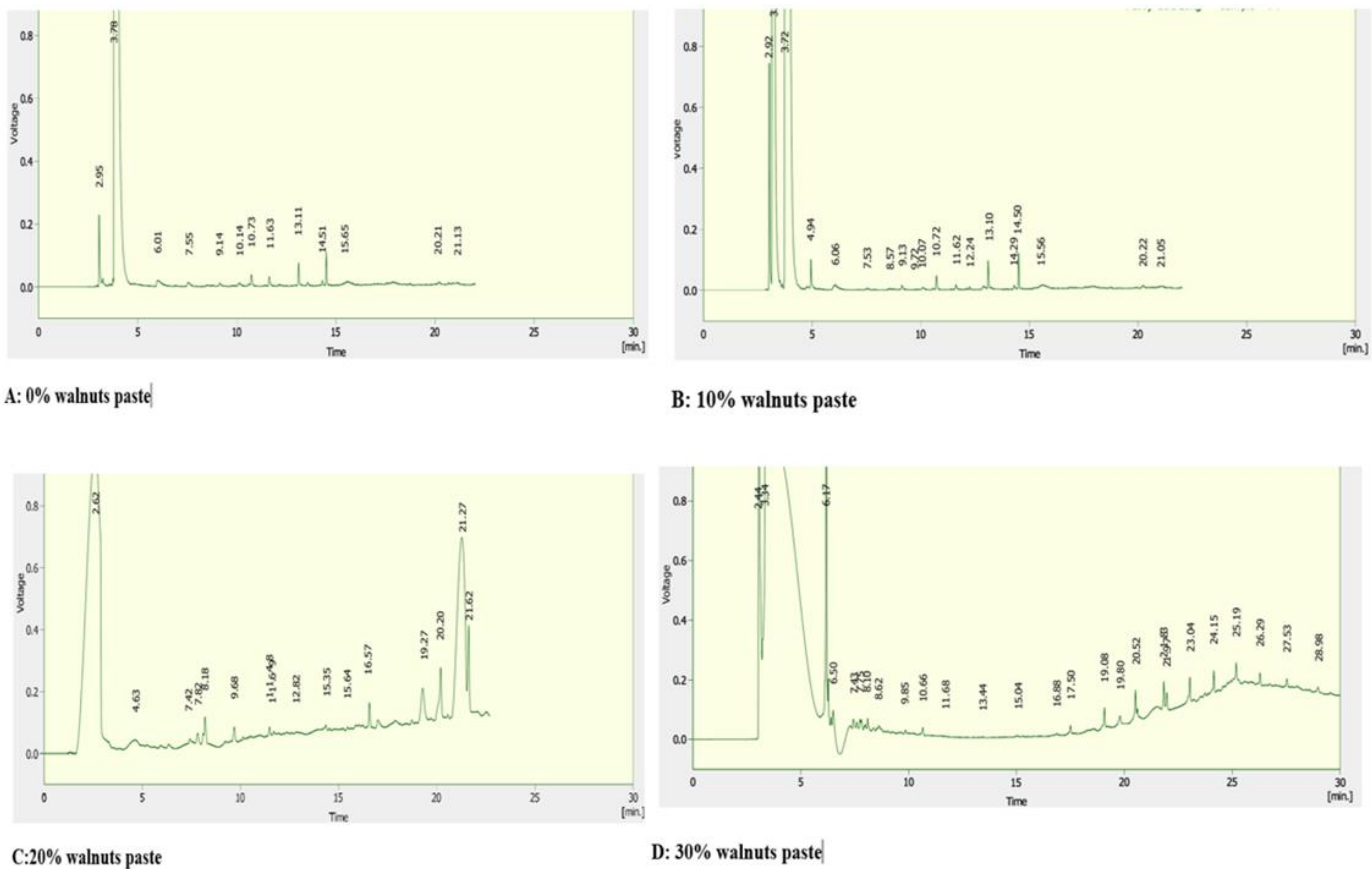

Figure 1: The long chain fatty acids analysis walnut processed cheeses containing (10, 20 and 30) % walnut paste by GC-MS.

3. 4 Sensory Evaluation of the process cheese

Table 3 shows the mean scores of flavors, texture, appearance, color, and overall acceptability of walnuts process cheese and control treatment. All the walnuts process cheese received high valuing for the different sensory ascribe suggesting that they were accepted by all the panelists. In general, walnuts processed cheeses with 10, 20 and 30% of added walnut presented the highest score for all sensorial ascribed compared with control cheese 0%walnut. Process cheese with 20% of added walnut superior for most of sensorial attributes compared with cheese containing10 or 30% walnuts. About flavor, the highest score was show with 20% walnut processed cheese, while the lowest score recorded with 10% then 30% and followed by control treatment. As to texture, is observed between the cheese-added walnuts paste and control cheese, although process cheese with 20% walnut had lower scores than other treatments but remain better than control cheese.

These results highlight that there was balance between the flavor of base cheese (Pesta cheese) and walnuts with 20% rather than 10% or 30% which was affect to decision of the panelist. 20% walnuts paste treatment did not different significantly at P≤ 0.05 from 10%walnuts paste treatment but were different from 30% walnuts paste treatment and control treatment, although that 20% walnuts paste was appearing more similarity to 30% walnuts in most sensory properties.

Table 3: Sensory evaluation of walnut process cheese containing 0, 10,20 and 30% walnut paste.

Attributes	0% Walnuts (Control)	10 % Walnuts	20 % Walnuts	30 % Walnuts
Appearance (20 score)	14.3 ±0.21 ^{c}	15.2 ±0.11 ^{b}	15.6±0.31 ^{b}	17.6 ±0.51 ^{a}
Flavor (35 score)	26.4 ±0.32 ^{c}	33.6 ±0.05 ^{a}	34.4±0.01 ^{a}	28.6 ±0.11 ^{b}
Texture (25 score))	16.6±0.35 ^{d}	21.4±0.09 ^{b}	20.0 ±0.08 ^{c}	23.2 ±0.11 ^{a}
Color (20 score)	15.6±0.01 ^{b}	15.2±0.07 ^{b}	19.4 ±0.33 ^{a}	18.8 ±0.22 ^{a}
Over acceptability (100 score)	72.9 ±0.00 ^{c}	85.4 ±0.01 ^{b}	89.4 ±0.01 ^{a}	88.2 ±0.00 ^{a}

The results were demonstrated as mean SD; means with different coordinating in a row differ significantly (p ≤0.05).

3. 5 Principal Components Analysis

According to the data of principle composition analysis of fatty acids, physiochemical, functional and sensory parameters of processed cheese treatments containing (0%, 10%, 20%, and 30%) walnuts paste were plotted together with a shared legend at the top of figure (2), in the left part of the figure PC1 (98.49% variance) explains nearly all of the differences, indicating strong separation among treatments, control (0%) walnuts paste was positioned on the far right, showing the most distinct profile, 10% walnuts paste lies closer to the center, suggestion moderate changes while 20% and 30% walnuts paste cluster together on the left high similarity between them, This indicates that increasing walnut content shifted the fatty acid composition significantly, with the most pronounced differences at 20% and 30%, while 10% showed an intermediate profile.

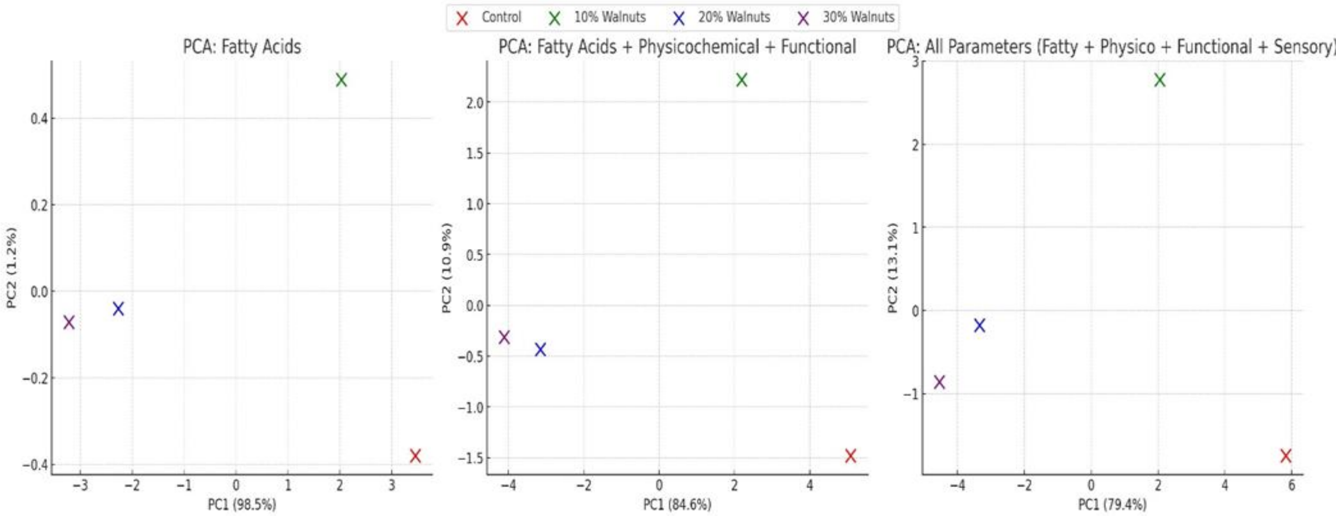

Figure 2: PCA similarity map obtained by principal components analysis of physicochemical, functional, sensory and long chain fatty acids parameters of processed cheese containing 0, 10, 20, and 30% walnut paste, left: PCA using only fatty acids. Middle: PCA using fatty acids + physiochemical + functional properties. Right: PCA using all parameters (fatty acids + physiochemical + functional properties + sensory).

The middle part of figure (2) combined PCA similarity map including fatty acids, physiochemical parameters (fat, protein, moisture, ash, NaCl, acidity and Ph) and functional parameters (meltability and oil separation index), PC1(84.56% variance) explains most of the separation, Control (0 % walnuts) was far from the walnut-containing samples, meaning it has a distinct overall profile, 10 % walnuts was somewhat intermediate, positioned closer to control but still shifted, but 20% and 30% walnuts cluster together on the left, indicating similar compositions and functionality, the similarity map showed that higher walnut addition(20-30)% results in strongly related characteristics, while the control was the most different.

The final PCA similarity map include fatty acids, physiochemical parameters, functional parameters and sensory properties, PC1(79.39% variance) explains the majority of variability across treatments, Control (0 % walnuts) was the most distinct, separated far to the right. 10 % walnuts occupies an intermediate position between control and higher walnut levels. 20% and 30% walnuts cluster closely together, showing high similarity in overall fatty acids, functional, and sensory profiles. Sensory attributes (especially flavor, texture, and overall acceptability) likely drive the closeness of 20% and 30% walnuts treatments. This map clearly showed that adding walnut paste significantly changes cheese characteristics, with 20% and 30% giving similar results.

4 Discussion

Walnuts constitute a lipid-rich source, containing 55-76% fat [19], The observed increase in fat content in walnut-supplemented cheeses likely derives from the inherent composition of added walnut paste [20]. The elevated acidity and reduced pH may be attributed to free fatty acids liberated from walnuts during cheese processing. Similar findings were reported by Abbas et al. [21], Enhanced meltability in walnut-containing cheeses suggests improved thermal fluidity compared to control samples. As previously noted, walnut addition modifies the compositional profile, particularly pH and total solids (Table 1), which critically influence rheological, textural, and melting behaviors through effects on casein-casein, casein-water, and mineral-casein interactions [22]. These results align with Awad et al. [23]. The progressive increase in oil separation index with higher walnut concentrations may result from walnut-induced modifications in cheese emulsion stability, promoting lipid separation from the protein matrix. The observations that the unsaturated fatty acids (USFA) (oleic, linoleic, linolenic) increase progressively with increase walnuts paste contents in treatments, that because the walnut contains high amount of the essential fatty acids [24,25,26], and due to the fact that walnuts rich in omega-3 and omega-6 [27]. Pereira and others reported that walnuts have a high amount of PUFAs as linolenic and linoleic acids and MUFAs as oleic acid [28]. Walnuts supplementation boosts both USFAs and SFAs, but the proportional increase is stronger for unsaturated fatty acids.

This suggests walnuts paste significantly enrich the lipid profile with beneficial unsaturated fatty acids, especially omega-3 and omega-6. Abbas *et al* [21] used walnuts paste at levels 5,10, and 15% to produced processed cheese and increased the nutritionally processed cheese. El-Loly *et al* [4] used papaya fruit pulp at levels 5,10, and 15% to produce the nutrition processed cheese. Hama Kawani *et al* [29] treated base milk of Queso Blanco Cheese with β-Cyclodextrin to reduction of cholesterol level from 2.37 mg/100g to 1.13 mg/100g

All the walnuts process cheese received high valuing for the different sensory attribute suggesting that they were well accepted by all the evaluates. The decrease in flavor in process cheese with 30% walnuts could be attributed to the over content of walnut and due to the over intensity of ripened pesta cheese flavor which was form 50% from the processed cheese. The results highlight that there was balance between the flavor of base cheese and walnuts with 20% rather than 10% or 30% which was affect to decision of the panelist, similar results in sensory analysis results were recorded when peanuts were added to process cheese [12]. El-Loly *et al* [4] used papaya fruit pulp as a naturally sweet flavor at levels 5,10, and 15% to produced processed cheese.

According to the data of principle composition analysis of fatty acids physicochemical, functional and sensory parameters of processed cheese treatments containing (0%, 10%, 20%, and 30%). Sensory attributes (especially flavor, texture, and overall acceptability) likely drive the closeness of 20% and 30% walnuts treatments. The map clearly showed that adding walnut paste significantly changes cheese characteristics, with 20% and 30% giving similar results. A main strength of this study is the evaluation of essential fatty acids levels in processed cheese boosted with walnut paste, which has not been previously mentioned in our region which is rich in walnuts and may contribute to improve human nutrition.

5 Conclusions

This study successfully developed a novel processed cheese fortified with walnut paste. Walnut paste incorporation at 10%, 20%, and 30% levels proved feasible, with the 20% formulation demonstrating optimal characteristics. Supplementation increased fat content (particularly unsaturated fatty acids: Oleic, Linoleic, and Linolenic acids) and ash value, while enhancing cheese matrix properties through improved meltability, though protein content decreased compared to control samples. These results establish walnut paste supplementation as a viable nutritional approach to increase beneficial fatty acids in processed cheese formulations.

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