CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: **https://chimie-biologie.ubm.ro/carpathian_journal/index.html**

IMPACT OF USING SOME FOOD INDUSTRY WASTES ON COMPOSITION AND QUALITY OF PROCESSED CHEESE SPREAD

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https://doi.org/10.34302/crpjfst/2024.16.2.3

Article history:
Received: January 10th, 2024
Accepted: March 12th, 2024
Keywords:
Food wastes;
Processed cheese spread;
Composition;
Quality properties.

ABSTRACT

This study investigated the effect of using some food industry wastes such as broken rice (BR), broken pasta (BP), and broken faba bean (BFB) on the physicochemical, textural, microstructure, and sensory properties of processed cheese spread (PCS). The BR, BP, and BFB were converted into flour (BRF, BPF, and BFBF, respectively) and added to processed cheese formulas at levels of 5, 10 and 15%. The results showed an increase in the values of total solids, fat, protein, ash, carbohydrates, fiber, and acidity in the processed cheese by adding the obtained flours, and these values were increased with increasing the addition level. The PCS containing BFBF had the highest values of protein, ash, and fiber compared to all the other treatments. The texture parameters (hardness, adhesiveness, cohesiveness, gumminess and chewiness) were increased by increasing the rate of addition of BRF, BPF, and BFBF compared to the control treatment. Also, it was found that the BRF and BPF improved the microstructure properties of the PCS samples. The sensory evaluation results showed that the highest degree of acceptance was with samples made using BPF at levels of 10% and 15%., while with BRF and BFBF the most acceptable values were observed with an addition level of 10% compared to the control.

1.Introduction

Processed cheese (PC), in the most generic terms, is a blend of one or more natural cheeses of different ages, emulsifying salts, water, and other dairy and nondairy ingredients. The mixture undergoes heating and continuous agitation to produce a pasteurized product that is homogeneous and has an extended shelf life (Meyer 1973; Thomas 1973; Kapoor and Metzger 2008). It may be of interest to note That PC was invented in 1911 in Switzerland by Walter Gerber and Fritz Stelter and developed in the USA in 1916 by J. L. Kraft (Kapoor and Metzger, 2008). The earlier studies carried out between 1958 and 2015 on factors affecting the properties and quality of PC was recently reviewed by Abd El-Kader (2017).

In addition to the nutritional considerations of the components of these wastes, their functional properties, such as oil and water absorption, solubility, emulsification properties, and stability, and increases in yield also contribute significantly to the final quality of processed food products. The utilization of other non-dairy ingredients in processed cheese production has opened up a wide range of food products with enhanced functional properties. A wide range of processed cheeses with diverse textures and flavors can be produced thanks to the wide variety of ingredients that can be added to processed cheese blends. As a result, processed cheese can be eaten alone or used to make other dishes, such as snacks. These characteristics and features make processed cheese among the most innovative products in the dairy sector. Therefore, the processed cheese market is always in need of more innovations aimed at improving the nutritional value and health benefits of the final product (Aly *et al.*, 2016) . All these substitutes including protein, fat and carbohydrate-based materials will lead to decrease production cost, provide flavour or texture, or improve the shelf life (Kapoor and Metzger, 2008). Relatively recent studies were done in Egypt to improve quality of market PC as well as to reduce cost of production via producing imitation or PC analogues. Such studies were reviewed-in details by Mehanna *et al.* (2016) and Dawoud (2021).

Recently, this trend has grown to provide nontraditional food additives that meet the need to fill the deficit in the quantities of food available for human consumption, and provide more diversity to the prevailing food dishes, and, on the other hand, contribute to maximizing the use of agricultural production residues (Rozan & Boriy, 2022) such as broken rice, broken pasta and broken faba bean (*Vicia faba*). However, more details about non-dairy ingredients from variety of plants and their use in dairy products were recently reviewed by Makinen *et al.* (2016); Tangyu *et al.* (2019).

In this context, the use of food waste plays an important role in achieving sustainable development. Exploiting these wastes provides opportunities to reduce waste, improve resource utilization, and promote the circular economy (Zhu *et al.* 2022). Food waste is materials resulting from some food production processes. These wastes are often neglected or used as animal feed. The types of food industry waste vary depending on the type of food industry involved in the process. The food industry generates large amounts of wastes, which is often overlooked as a valuable resource. There is a growing interest in the importance of recycling these wastes and reintegrating them into the value chain to achieve sustainable development principles. Among these wastes are broken rice, broken pasta, and broken beans.

Broken or ground rice refers to the fragments of rice grain obtained by milling. This product is separated after the polishing phase and has the same chemical composition of white rice, and its use is common in animal fodder. Broken rice is rejected by the consumer market and, for the most part, is intended for animal feed, for brewing industry, fertilizer etc. Forms of use of this product generated during rice processing, aiming to add value to it, is necessary since the incorporation of these in food formulations could solve the great waste arising from rice processing, and become an alternative form of income. According to Tavares *et al.* (2016).

Rice like cereals is carbohydrate-rich food. Carbohydrates of rice are predominantly starch with small portions of pentosans, hemicelluloses and sugars. The second most abundant constituent is protein and the major protein fractions are glutenin, albumin, globulin, and prolamin. Rice protein has one of the highest nutritive values among cereal proteins because of its lysine content (Bandyopadhyay & Roy, 1992). The nutritional level of rice is high among cereals and other grains and it has a comparatively high content of essential amino acids with high total digestibility of protein (Pillaiyer, 1988).

Broken pasta refers to the fragments of pasta obtained during the manufacturing process. This product is separated before the packing process phase and has the same chemical composition as Pasta. Pasta is one of the most important foods consumed around the world due to its relatively low cost and desirable organoleptic properties (Oyeyinka *et al.*, 2021) . Pasta is a rich source of carbohydrates and an acceptable source of vegetable protein (Oyeyinka *et al.*, 2021).

Broken Faba beans are known to be a potent resource of protein, and are commonly used in animal feed. They are widely known as 'Poor man's meat', the main plant source of proteins in the human diet. They are also generally rich in dietary fiber and carbohydrates (Rochfort & Panozzo., 2007).

Furthermore, grain legumes contain antioxidants and other bioactive compounds that can contribute to human health (Ganesan & Xu.,2017). Several health benefits have been proposed in relation to the consumption of grain legumes, including reduced risk of colorectal cancer (Aune *et al.*, 2011), improvement of gut health, and reduced blood cholesterol levels (Clemente & Olias, 2017).

The objective of the present study was to use broken rice, broken pasta and broken faba bean in making processed cheese spread. The composition and quality of the prepared processed cheese were taken into consideration hoping to reduce the cost of the production by replacing part of the natural cheese by the above-mentioned materials.

2. Materials and methods

2.1. Raw Materials

Ras cheese was manufactured using fresh cow's milk as the procedure of Hofi *et al.*, (1970) in Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. While matured Cheddar cheese (8 months old), was purchased from the local market in Giza, Egypt. Broken rice (BR), broken pasta (BP), and broken faba bean (BFB) were also purchased from the local market and converted into flour form according the procedure of Awad (2007) using laboratory mill (National, Japan), and then sieved through a 0.1mm mesh sieve. The resultant flours were packed in polyethylene bags and stored in the refrigerator (4±1°C) until use. The chemical composition of raw materials is shown in Table (1).

Table 1. Chemical composition of raw materials used in the manufacture of processed cheese spreads

Composition (%)	Ras Cheese	Cheddar Cheese	Butter	(BRF)	(BPF)	(BFBF)
Total solids	54.22	65.70	85.00	90.38	92.29	97.08
Fat	25.56	34.80	82.22	0.20	1.52	1.68
Protein	22.12[1]	25.77[1]	ND[2]	7.78[3]	10.69[4]	29.12[5]
Ash	4.73	5.03	ND[2]	0.66	0.99	3.47
Carbohydrate	1.81	0.10	ND[2]	81.53	78.56	50.07
Fiber	ND[2]	ND[2]	ND[2]	0.21	0.50	3.90

BRF: broken rice flour; BPF: broken pasta flour; BFBF: broken faba bean flour.
1: Protein% = N × 6.38 2: Not determined 3: Protein% = N × 5.17
4: Protein% = N × 5.33 5: Protein% = N × 5.52.

2.2. Methods

2.2.1. Manufacture of processed cheese spreads (PCSs)

Processed cheeses spread (PCSs) were manufactured according to the method of Meyer (1973). Control treatment samples were prepared using fresh Ras cheese and mature Cheddar cheese as a base blend. Meanwhile, other processed cheese treatments (BRF, BPF, and BFBF) were manufactured by replacing the natural cheese in the base blend with broken rice flour, broken pasta flour and broken faba beans flour at ratios of 5, 10 and 15%. The different formulations used to prepare processed cheese are shown in Table 2. Three replicates were carried out from each treatment. The composition of each batch of final processed cheese treatments was adjusted to 55-58 % moisture, 45-50 % fat /dry matter, and the pH value was between 5.6 – 5.9. Simultaneously required amount of emulsifying salts (2.5 %), butter and water were added and mixed using ultra turrax homogenizer for 5 – 10 min on 10 par and heated for a final temperature of 82°C in approximately 4 min then filled into plastic containers (120g) and rapidly cooled at 7 ±1°C. The final products were stored in refrigerator at 4±1°C for 3 months, and all treatments samples were analyzed for physicochemical composition, texture properties, and sensory evaluation at 0, 1, 2, and 3 months of cold storage.

2.2.2. Physicochemical analysis.

The chemical analysis (total solids (%), protein (%), fat (%) and ash (%)) of PCSs samples were tested for and was carryout according to the AOAC procedure (AOAC 2005) Total carbohydrates were calculated by differences as described, whereas fiber content was also determined (AOAC 1990). The acidity (%) of cheese was determined according to the method of Ling (1963), and pH values were measured using a digital laboratory pH meter

(HI 93 1400, Hanna instruments) with a glass electrode.

Table 2. Composition of different blend formulas (Kg/100Kg) used in manufacture of spreads processed cheese (PCSs) with different ratios of broken rice flour, broken pasta flour and broken faba bean flour in the base bland

Ingredients (%)	Control	BRF			BPF			BFBF		
		5 %	10 %	15 %	5 %	10 %	15 %	5 %	10 %	15 %
Ras cheese	38.44	37.44	35.32	33.56	37.44	35.32	33.56	37.44	35.32	33.56
Cheddar cheese	12.80	11.25	10.80	10.00	11.25	10.80	10.00	11.25	10.80	10.00
Butter	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26
Emulsifying salts	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Food wastes	-	2.55	5.12	7.68	2.55	5.12	7.68	2.55	5.12	7.68
Salt	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Water	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
Total	100	100	100	100	100	100	100	100	100	100

BRF: broken rice flour; BPF: broken pasta flour; BFBF: broken faba bean flour.

2.2.3. Oil separation index

Oil separation was determined according to the method outlined by Thomas (1973) as follow:

A cork borer was used to obtain cylindrical sample of processed cheese approximately 17.0 × 17.0 mm. the sample was pressed gently between tow sheets of Whatman No. 41 filter paper and incubated at 45 ºC for two hours. The diameter of the spread oil was measured in mm and was used as an index of oil separation according to the following equation

$$OSI = (D2 - D1) / D1 \times 100$$

Where:

OSI: Oil separation index

D1: Diameter of cheese fat before heating

D2: Diameter of cheese fat after heating

2.2.4. Meltability

Meltability of cheese was measured in duplicate by using the melting test as described by Olson and Price (1958) with the modification of Rayan *et al.* (1980). A cylinder of cheese sample (15±0.2g) was put in a Pyrex glass tube, 30 mm in diameter and 250 mm long and a reference line was marked on the tube aligned with the front edge of the cheese sample. The tube was immediately placed in horizontal position in an oven at 110ºC for 30 mins. The distance of flow from the reference line to the leading edge of the melted cheese was quickly measured and recorded in mm as cheese flow or as cheese meltability.

2.2.5. Texture profile analysis (TPA)

Texture properties of PCSs samples were determined at 23°C as described by Bourne (1982) using an Instron Universal Testing Machine model 1195, Stable Micro System (SMS) Ltd., Godalming, UK, loaded with Dimension Software SMS program.

2.2.6. Microstructure of Processed Cheese

The microstructure of the processed cheese was evaluated by scanning electron microscopy according to the method of Tahmasebi *et al.*, (2015). Small pieces of fresh specimens of processed cheese samples were removed and fixed by immersing them immediately in 4F1G (fixative, phosphate buffer solution), pH 7.4 at 4°C for 3 hours. Specimens were then postfixed in 2% OsO_4 in the same buffer at 4°C for 2 hours. Samples were washed in the buffer and dehydrate at 4°C through a graded series of ethanol. Samples of processed cheese were dried by means of a critical point method, mounted using carbon paste on an AL-stub and coated with gold up to a thickness of 400 A in a sputter-coating unit (JFC-1100E). The observation of processed cheese morphology in the coded specimens was performed in a JEOL JSM-IT200 scanning electron microscope operated between 15 and 20 KeV, and an irradiation current of 10 μm.

2.2.7. Organoleptic assessment

The organoleptic properties of PCS samples were evaluated by 15 regular panelists of the staff members at the Dairy Department, Al-Azhar University, and Dairy Department, Food Technology Research Institute, Agricultural Research Center according to the scheme of Meyer (1973).

2.2.8. Statistical analysis

All the data were statistically analyzed by the SPSS statistical software using one-way ANOVA. Analysis of variance and Duncan's test as well as average were carried out using SPSS computer program (SPSS, 2016; version 24) at P≤ 0.05.

3.Results and discussions

3.1. Chemical composition of PCSs

The changes in the gross chemical composition of PCSs made with replacement of the natural cheese in the base blend with BRF, BPF and BFBF (at 5, 10 and 15%) are shown in Table (3). The results showed that there were noticeable differences in the total solids and fat contents of PCSs due to applied replacements. These differences may be due to differences in the quantity and chemical composition of the materials used in the manufacture. The contents of total protein, ash and fiber of the treated PCSs with BFBF were significantly higher comparing with the other treatments and the control cheese. As well known, the dairy ingredients used never contain any dietary fiber, so the added food waste (FW) is considered a source of dietary fiber therefore thus a gradual increase in the proportion of (FW) was associated with a significantly proportional increase in the proportion of fiber in the treated PCSs Omar *et al.* (2012).

The contents of total protein, ash and fiber of the PCSs were significantly higher in PCS with BFBF compared with the other treatments and the control, and increased with increasing the proportion of replacement BFBF in the blend. This was expected and could be due to the chemical composition of broken BFBF this result agrees with Omar *et al.* (2012).

On the other hand, carbohydrate content in PCS was increased with an increase in the proportion of substituted BRF in the mixture compared with the other treatments and the control cheese due to the chemical composition of broken rice and its high carbohydrate content (Bandyopadhyay & Roy, 1992).

3.2 Acidity and pH values:

Fig. (1) shows that the acidity values of the control cheese samples were almost less than those of the treated samples. This was true in fresh and stored cheese. However, slightly higher values were recorded in case of using broken pasta flour in fresh cheese comparing with the control or the other food wastes used, but in all cases the higher was the ratio of the food waste used, the lower was the acidity value. Such changes were almost insignificant (P>0.05), while storage of cheese samples had significant impact (P≤ 0.05) on increasing the acidity values.

Data of pH shown in Fig. (2) revealed that the control sample had almost higher pH value than the treated cheese and this was recorded in case of fresh and stored cheese samples. On the other hand, the higher was the amount of the food waste, the lower were the pH values. Relatively lower pH values were recorded in case of using the broken beans. However, significant higher values were noticed in fresh cheese samples suggesting cold storage had decreasing impact in this respect. Such impact was significant in many cases and could be attributed to decomposition of protein and lactose during storage. The attained results are in general with those given in the literature by Tamime *et al.* (1990); Younis *et al.* (1991); Aly *et al.* (1995), Chambre and Daurelles (2000), Abdel-Hamid *et al.* (2000, a); Awad (2003); Awad *et al.* (2003) and Tohamy *et al.* (2018).

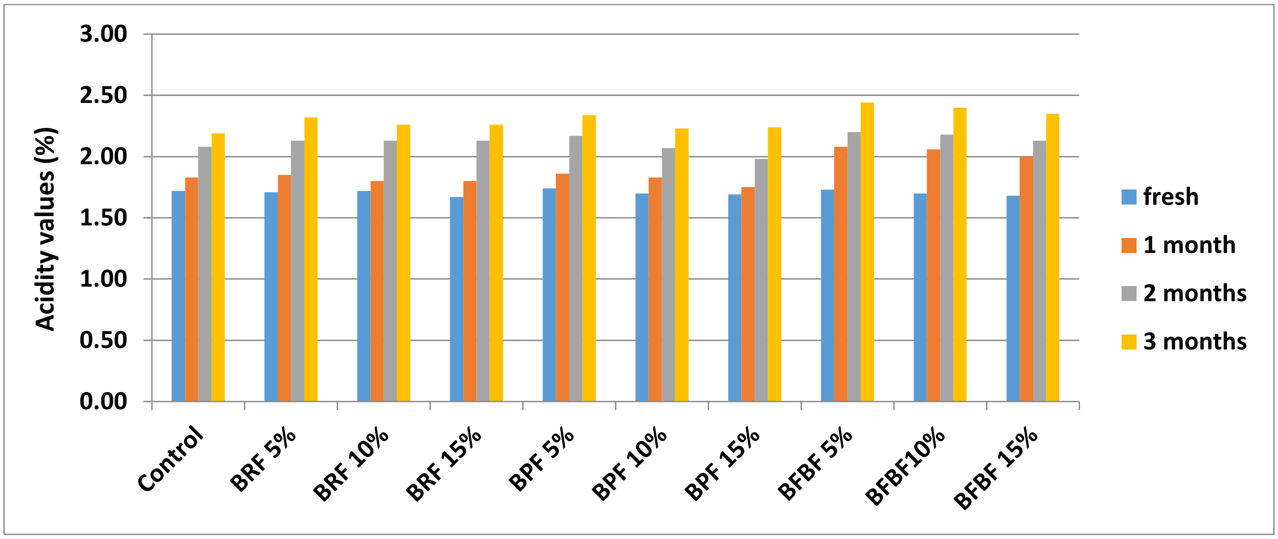


Figure 1. Changes in the acidity (%) values of processed cheese spreads supplemented with different ratios of BRF, BPF, and BFBF during cold storage (4°C) for 3 months.

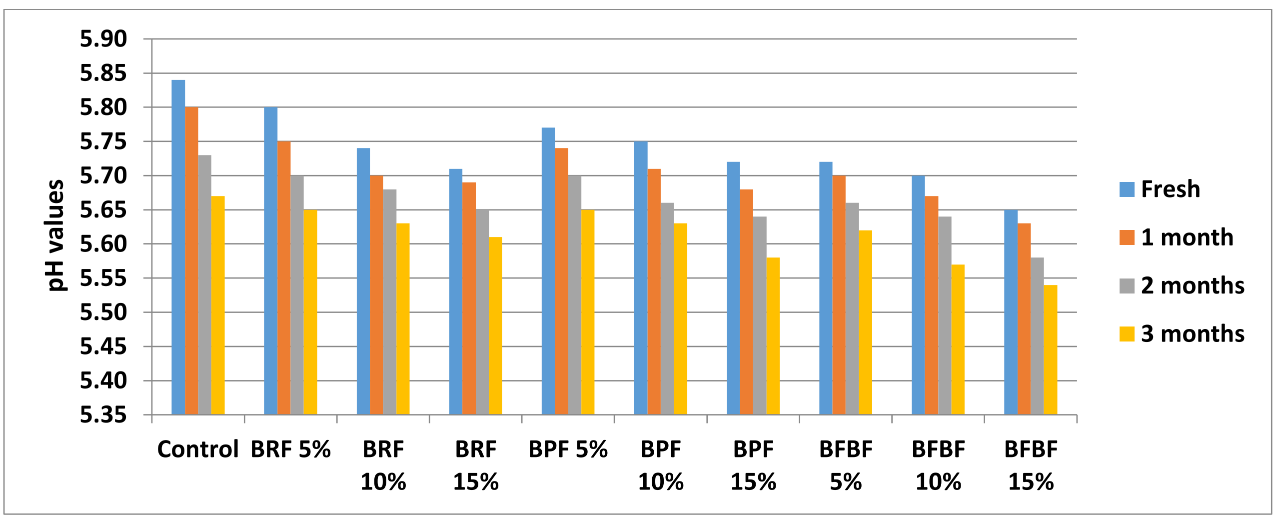


Figure 2. Changes in the pH values of processed cheese spreads supplemented with different ratios of BRF, BPF, and BFBF during cold storage (4°C) for 3 months.

Table (3). Chemical composition of processed cheese spreads (PCSs) made with different ratios of BRF, BPF, and BFBF during cold storage at 4 °C for 3 months.

Parameters	Storage (month)	Control	BRF			BPF			BFBF		
			5%	10%	15%	5%	10%	15%	5%	10%	15%
Total solids (%)	0	45.55±0.126^{fD}	46.02±0.185^{deC}	46.21±0.210^{cdC}	46.84±0.165^{bD}	45.76±0.185^{efC}	46.35±0.095^{cC}	46.99±0.100^{bD}	47.37±0.135^{aC}	47.46±0.135^{aC}	47.56±0.220^{aC}
	1	45.71±0.010^{fC}	46.19±0.055^{dC}	46.32±0.045^{dC}	47.04±0.080^{bC}	45.92±0.020^{eC}	46.56±0.13^{cB}	47.19±0.035^{bC}	47.48±0.240^{aC}	47.58±0.035^{aC}	47.65±0.060^{aC}
	2	46.27±0.040^{fB}	46.64±0.040^{eB}	46.70±0.075^{eB}	47.31±0.030^{dB}	46.30±0.055^{fB}	46.71±0.030^{eB}	47.61±0.045^{cB}	47.930.045±^{bB}	48.00±0.020^{bB}	48.11±0.045^{aB}
	3	46.67±0.015^{gA}	47.10±0.010^{fA}	47.14±0.005^{fA}	47.77±0.025^{eA}	46.70±0.020^{gA}	47.10±0.010^{fA}	48.06±0.020^{dA}	48.28±0.045^{cA}	48.38±0.020^{bA}	48.45±0.015^{aA}
Fat (%)	0	23.51±0.010^{bD}	23.48±0.040^{bC}	23.49±0.035^{bC}	23.51±0.040^{bC}	23.58±0.015^{aC}	23.60±0.005^{aD}	23.62±0.005^{aD}	23.50±0.040^{bC}	23.51±0.035^{bC}	23.52±0.060^{bC}
	1	23.56±0.010^{bC}	23.52±0.040^{bC}	23.54±0.035^{bC}	23.54±0.040^{bC}	23.63±0.015^{aC}	23.67±0.005^{aC}	23.68±0.005^{aC}	23.54±0.040^{bC}	23.55±0.035^{bC}	23.57±0.060^{bC}
	2	23.62±0.035^{dB}	23.62±0.045^{dB}	23.63±0.040^{cdB}	23.68±0.040^{bcdB}	23.70±0.045^{bcB}	23.74±0.025^{bB}	23.82±0.040^{aB}	23.64±0.020^{cdB}	23.68±0.045^{bcdB}	23.70±0.045^{bcB}
	3	23.78±0.025^{eA}	23.89±0.010^{cA}	23.90±0.015^{cA}	23.94±0.010^{bA}	23.93±0.020^{bcA}	23.96±0.030^{bA}	24.12±0.015^{aA}	23.81±0.020^{deA}	23.83±0.025^{dA}	23.85±0.045^{dA}
Protein (%)	0	14.87±0.020^{bC}	13.68±0.035^{dB}	13.71±0.040^{dB}	13.73±0.040^{dC}	13.78±0.015^{cC}	13.80±0.010^{cC}	13.82±0.010^{cB}	15.34±0.045^{aC}	15.37±0.025^{aC}	15.39±0.030^{aC}
	1	14.94±0.045^{bC}	13.70±0.055^{dB}	13.73±0.035^{dB}	13.79±0.040^{dC}	13.85±0.040^{cBC}	13.87±0.55^{cBC}	13.89±0.45^{cB}	15.37±0.025^{aC}	15.39±0.070^{aC}	15.42±0.060^{aC}
	2	15.20±0.055^{bB}	13.83±0.065^{eA}	13.85±0.040^{deA}	13.87±0.030^{deB}	13.89±0.055^{deAB}	13.92±0.045^{dAB}	14.10±0.060^{cA}	15.57±0.010^{aB}	15.58±0.045^{aB}	15.62±0.040^{aB}
	3	15.30±0.020^{cA}	13.89±0.020^{gA}	13.91±0.015^{fgA}	13.97±0.025^{eA}	13.95±0.025^{efA}	13.98±0.015^{eA}	14.05±0.040^{dA}	15.68±0.025^{bA}	15.70±0.035^{abA}	15.73±0.025^{aA}
Ash (%)	0	3.77±0.045^{cB}	4.02±0.040^{bB}	4.09±0.010^{aB}	4.10±0.030^{aB}	4.02±0.045^{bB}	4.10±0.020^{aA}	4.12±0.035^{aB}	4.13±0.035^{aB}	4.15±0.030^{aB}	4.15±0.045^{aB}
	1	3.79±0.035^{dB}	4.04±0.065^{cB}	4.10±0.55^{bdB}	4.12±0.040^{abcB}	4.04±0.025^{cB}	4.12±0.55^{abcA}	4.15±0.045^{abB}	4.14±0.025^{abB}	4.18±0.025^{abAB}	4.19±0.035^{aAB}
	2	3.90±0.040^{dA}	4.13±0.020^{abcA}	4.14±0.020^{abcA}	4.14±0.020^{abcB}	4.10±0.085^{cAB}	4.12±0.025^{bcA}	4.18±0.010^{abB}	4.17±0.025^{abAB}	4.18±0.025^{abAB}	4.20±0.025^{aAB}
	3	3.96±0.030^{eA}	4.18±0.025^{cdA}	4.18±0.020^{cdA}	4.20±0.025^{bcA}	4.15±0.020^{dA}	4.17±0.025^{cdA}	4.24±0.025^{aA}	4.20±0.025^{bcA}	4.23±0.025^{abA}	4.25±0.020^{aA}
Carbohydrate (%)	0	3.40±0.060^{dB}	4.72±0.040^{bC}	4.78±0.090^{bB}	5.30±0.030^{aB}	4.24±0.085^{cB}	4.70±0.020^{bB}	5.22±0.005^{aB}	4.17±0.010^{cB}	4.19±0.020^{cB}	4.26±0.040^{cB}
	1	3.42±0.100^{dB}	4.78±0.105^{bBC}	4.80±0.07^{bAB}	5.38±0.040^{aB}	4.25±0.040^{cB}	4.74±0.055^{bAB}	5.25±0.075^{aB}	4.19±0.025^{cB}	4.20±0.075^{cB}	4.28±0.035^{cAB}
	2	3.55±0.035^{gA}	4.87±0.055^{cAB}	4.89±0.065^{cAB}	5.40±0.005^{aA}	4.45±0.020^{eA}	4.75±0.045^{dAB}	5.28±0.010^{bB}	4.27±0.025^{fA}	4.28±0.015^{fA}	4.30±0.025^{fAB}
	3	3.63±0.035^{fA}	4.92±0.20^{bA}	4.93±0.20^{bA}	5.41±0.40^{aA}	4.47±0.20^{dA}	4.79±0.30^{cA}	5.42±0.40^{aA}	4.29±0.40^{eA}	4.31±0.30^{eA}	4.33±0.25^{eA}
Fiber (%)	0	0.00	0.12±0.030^{bC}	0.14±0.035^{bB}	0.20±0.025^{aA}	0.14±0.025^{bB}	0.15±0.040^{bA}	0.21±0.045^{aA}	0.23±0.005^{aB}	0.24±0.025^{aA}	0.24±0.045^{aA}
	1	0.00	0.15±0.015^{bBC}	0.15±0.020^{bB}	0.22±0.015^{abA}	0.15±0.005^{bB}	0.16±0.030^{bA}	0.22±0.040^{abA}	0.24±0.055^{aB}	0.26±0.065^{aA}	0.28±0.080^{aA}
	2	0.00	0.19±0.045^{cdAB}	0.19±0.045^{cdAB}	0.21±0.025^{cdA}	0.16±0.015^{dB}	0.18±0.025^{cdA}	0.23±0.035^{bcA}	0.28±0.010^{abAB}	0.28±0.010^{abA}	0.29±0.055^{aA}
	3	0.00	0.22±0.030^{bcA}	0.22±0.010^{bcA}	0.25±0.025^{bA}	0.20±0.020^{dA}	0.20±0.005^{dA}	0.23±0.35^{bcA}	0.30±0.20^{aA}	0.31±0.040^{aA}	0.31±0.005^{aA}

* Means ±SD, means with the different small letters within the same row and means with different capital letters within the same column are significantly different ($P \leq 0.05$).
BRF: broken rice flour; BPF: broken pasta flour; BFBF: broken faba bean flour.

Table (4). Oil separation index (%) values of processed cheese spreads made with different ratios of the broken materials used

Storage period	Control	BRF			BPF			BFBF		
		5 %	10 %	15 %	5 %	10 %	15 %	5 %	10 %	15 %
Fresh	39.89±0.60cC	40.80±0.51cD	40.80±1.27cC	42.55±0.66bC	42.55±0.02bD	43.20±0.66bD	46.23±0.33aD	40.73±0.03cD	40.51±0.72cD	43.21±0.11bC
1 month	43.11±0.11dB	42.93±0.52dC	44.38±0.04cB	45.42±0.01bB	44.18±0.08cC	45.32±0.02bC	48.29±0.02aC	43.31±0.03dC	43.31±0.60cC	45.20±0.03bB
2 months	43.8±0.61dB	45.12±0.04cB	45.50±0.06cAB	46.56±0.08bA	46.67±0.01bB	46.64±0.53bB	49.31±0.03aB	44.21±0.02dB	45.27±0.04cB	46.95±0.61bA
3 months	46.28±0.04eA	46.17±0.04eA	46.52±0.02eA	46.58±0.53eA	47.72±0.61cA	48.84±0.04bA	52.20±0.02aA	46.75±0.04deA	47.60±0.51cdA	47.60±0.52cA

* Means ±SD, means with the different small letters within the same row and means with different capital letters within the same column are significantly different (P≤ 0.05). BRF: broken rice flour; BPF: broken pasta flour; BFBF: broken faba bean flour.

Table (5). Meltability (mm) values of processed cheese spreads made with different ratios of the broken materials used

Storage period	Control	BRF			BPF			BFBF		
		5 %	10 %	15 %	5 %	10 %	15 %	5 %	10 %	15 %
Fresh	128±1.00aA	126±0.00aA	126±2.00aA	125±3.00abA	126±1.00aA	125±2.00abA	120±1.00cA	121±2.00bcA	118±4.00cA	117±4.00cA
1 month	125±1.00aB	124±1.00aA	120±1.00bcB	120±1.00bcB	121±1.00bB	120±1.00bcB	119±1.00cA	120±1.0bcAB	117±1.00dAB	116±1.00dA
2 months	123±1.00aC	123±3.00aA	120±1.00abB	117±3.00bB	118±1.00bC	113±1.00cC	113±1.00cB	118±1.00bB	113±2.00cB	111±1.00cB
3 months	120±1.00aD	119±1.00aB	113±1.00bC	111±1.00bcC	112±2.00bcD	110±1.00cD	107±2.00dC	113±1.00bC	107±2.00dC	104±1.00eC

* Means ±SD, means with the different small letters within the same row and means with different capital letters within the same column are significantly different (P≤ 0.05). BRF: broken rice flour; BPF: broken pasta flour; BFBF: broken faba bean flour.

3.3. Oil separation index and Meltability

The oil separation indicator is a defect described for PCS. Separated oil deteriorates quickly due to exposure to oxidation The data presented in Table (4) indicate that the control cheese sample had the lowest fat separation index 39.89 %when it was fresh compared to the treatments containing broken (rice, pasta, and faba beans). While, samples of processed cheese treated with (BPF) at a level of 15% showed the highest index of oil separation 46.23 and 52.20% respectively, when it was fresh and at the end of the storage period. While samples of PCS treated with (BFBF) at a level of 5% recorded the lowest index of fat separation 40.73 and 44.21% respectively, when it was fresh and at the end of the storage period. That can be mainly attributed to the protein nature of those residues which may affect the degree of emulsification of the product.

The value of the oil index depends on the fat and protein status of the resulting processed cheese emulsion. In general, the values of the oil separation index gradually increased in all treatments including control cheese with the increasing replacement ratio and also with the progress storage period of processed cheese. This may be due to the changes in pH and soluble nitrogen content along with the melting salt-protein interactions could be the main contributors to increasing the oil separation. Similar results were obtained by Awad and Salama (2010 a,b) and Tawfek (2018).

Meltability is the capacity of cheese particles to flow together and form a uniform continuous melt. Melting is an important character which use to determine the resistance of processed cheese against changes of temperature during transportation and storing. Therefore, as meltability decreased the quality of processed cheese improved (Abbas, 2003). The results in Table (5) showed that the meltability values of the treated PCS decreased in proportion to the increase the percentages of using BRF, BPF and BFBF compared to the control cheese samples. Reducing the meltability by adding these broken materials in PCS can be attributed to increasing the hardness of the resulting cheese samples, which is consistent with El-Shibiny *et al.* (2013). Combined with the cold storage period.

After 60 days of cold storage the meltability values were significantly (P≤ 0.05) decreased in all treatments comparing with the fresh and the control cheese samples. Cold storage led to decrease in meltability of PCS because of the changes occurred in chemical properties of processed cheese such as pH, protein state, and product setting (Olson and Price, (1958); Abd El-Salam *et al.*, (1996); Abd El-Hamid *et al.*, (2000 b); Awad *et al.*, (2003, 2004); Mohamed (2004); Awad and Salama, (2010 a, b).

3.4. Texture profile analysis (TPA)

Texture profile analysis (TPA) is affected by several factors such as pH value, state of protein network, fat and moisture content. The results given in Table (6) showed that the firmness values of all treatments significantly (P≤ 0.05) increased during the storage period (4±1°C for 3 months). These findings concur with those of El-Sayed, et al (2020) who discovered that 120 days of storage at 4 °C resulted in a significant (P<0.05) increase in the hardness of UHT-processed cheese. The increase in firmness of processed cheese is associated with a decrease in its moisture content. Cheese made with broken faba beans had higher values for hardness, adhesiveness, cohesiveness and chewiness than control. This was true in fresh and stored cheese samples and the values gradually increased with increasing the amount of the BFBF added. The results illustrated that the values of all the rheological properties tested except springiness in all processed cheese samples were significantly (P≤ 0.05) increased during cold storage, these results are consistent with the observations of Cunha, *et al.* (2010).

This means that in all processed cheese samples springiness values gradually decreased with increasing the amount of broken food wastes added from one side and with advancing storage period from the other-side. The decrease in moisture content and increase of DM% especially protein content may by the reason for the increase in the hardness of cheese. This result agrees with Awad *et al.*, (2006).

Moreover, the increase in hardness of stored cheese may be due to the decrease in moisture content and less availability of water during storage, and consequently change of texture properties.

The functional and physical properties of cheese samples are significantly impacted by the composition of the processed cheese, which can change depending on differences in moisture content, pH, and protein content (Lee and Anema 2009).

In this respect, Mehanna, et al (2020) mentioned that the rheological properties of PCS were affected by the composition of the blends used since the lowest values of hardness, gumminess, springiness, cohesiveness, chewiness, and adhesiveness were recorded when PCS was made from blends containing the highest amount of Ras cheese (20%) and the lowest amount of SMP (5.5%).

3.5. Microstructure of Processed Cheese

Scanning electron micrographs (Fig. 3) show the protein network structure and fat globules sizes of the processed cheese samples containing rice (BRF), pasta (BPF), and beans (BFBF) flour in comparison with the control sample. The results showed that there were significant differences in protein network structure and the distribution of fat globules in processed cheese containing rice, pasta, and beans flour, comparing with the control.

In the BRF treatment samples, the protein and fat network appeared swollen, and densely packed, and the texture was more homogeneous than the control, and there were some fat-free globules. This swelling and appeared homogeneity may be due to the presence of a large amount of starch in the rice flour, which swells and increases in size after absorbing water.

Starch also plays role as stabilizer in processed cheese, which improves the texture characteristics. In the case of processed cheese containing pasta flour (BPF), the results showed good emulsification of fat similar to that in the treatment BRF, but the protein network structure was different, as it appeared in the form of inhomogeneous threads and agglomerates. As for the processed cheese samples containing bean flour (BFBF), there was the most difference compared to the control or the rest of the other treatments. It was found that the microstructure of cheese

It may be important to reveal that in our study we used SEM in the microstructure of processed cheese made with 10% of the aforementioned food waste because this Ratio improved the sensory properties of the processed cheese as well as slightly improving the chemical composition without any adverse effect on the quality characteristics of PCSs, which was recorded with a ratio of 15%. Also, there were no significant differences between the PCSs made with a ratio of 5% and the control sample (C) in terms of the sensory acceptance characteristics for the cheese product.

3.6. Sensory evaluation of PCS samples:

Sensory evaluation is a scientific method used to evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, hearing, touch, smell and taste (Stone and Sidel 1993; IFT 2007).

Scores of the different sensory attributes of PCS samples are shown in Fig.4. It seems from the attained results that the use of 5% of each of BRF, BPF and BFBF did not affect the flavour of PCS compared to the control sample, while an improvement in the flavor of the cheese was recorded when all food waste was used at levels of 10% and 15% except the BFBF the scoring points significantly decreased at level of 15% in fresh PCS and also during storage. Advancing cold storage period had no effect in this respect and this was true in the control and all treated PCS samples, except for the treatment with BFBF.

Table 6. Texture profile analysis (TPA) of processed cheese spreads made with different ratios of BRF, BPF, and BFBF during cold storage at 4 °C for 3 months.

Parameters	Storage Period (Month)	Control	BRF			BPF			BFBF		
			5%	10%	15%	5%	10%	15%	5%	10%	15%
Hardness (N)	0	2.16±0.045^{cD}	2.22±0.005^{cD}	2.33±0.020^{cC}	2.59±0.010^{bB}	2.18±0.015^{cD}	2.29±0.010^{cD}	2.53±0.010^{bD}	2.61±0.295^{bC}	3.34±0.120^{aC}	3.42±0.130^{aC}
	1	2.28±0.070^{cC}	2.31±0.055^{cC}	2.36±0.025^{cC}	2.71±0.045^{bB}	2.35±0.050^{cC}	2.37±0.020^{cC}	2.74±0.100^{bC}	2.82±0.160^{bB}	3.56±0.110^{aB}	3.66±0.115^{aB}
	2	2.40±0.060^{dB}	2.45±0.020^{dB}	2.51±0.025^{dB}	2.76±0.190^{cB}	2.51±0.035^{dB}	2.47±0.015^{dB}	3.08±0.105^{bB}	3.12±0.020^{bB}	3.69±0.005^{aB}	4.75±0.025^{aB}
	3	3.03±0.010^{dA}	3.07±0.025^{dA}	3.13±0.010^{cdA}	3.25±0.065^{cA}	3.11±0.010^{dA}	3.16±0.045^{cdA}	3.26±0.050^{cA}	3.65±0.205^{bA}	4.16±0.055^{aA}	4.20±0.015^{aA}
Adhesiveness (mJ)	0	1.105±0.010^{dD}	1.099±0.025^{dD}	1.113±0.011^{dD}	1.219±0.014^{bD}	1.123±0.020^{dD}	1.226±0.030^{bD}	1.239±0.035^{bD}	1.164±0.015^{cD}	1.244±0.040^{bD}	1.291±0.005^{aD}
	1	1.267±0.045^{eC}	1.282±0.006^{deC}	1.298±0.005^{deC}	1.311±0.010^{dC}	1.356±0.005^{cC}	1.372±0.015^{cC}	1.387±0.035^{cC}	1.316±0.005^{dC}	1.649±0.005^{bC}	1.716±0.025^{aC}
	2	1.200±0.020^{dB}	1.426±0.041^{dB}	1.463±0.020^{dB}	1.671±0.020^{cB}	1.459±0.030^{dB}	1.471±0.047^{dB}	1.667±0.058^{cB}	1.494±0.021^{dB}	1.825±0.030^{bB}	1.958±0.047^{aB}
	3	2.105±0.036^{eA}	2.250±0.052^{deA}	2.426±0.025^{cA}	2.936±0.041^{bA}	2.284±0.025^{dA}	2.263±0.047^{cA}	2.946±0.058^{bA}	2.283±0.030^{dA}	3.100±0.020^{aA}	3.163±0.015^{aA}
Cohesiveness (Ratio)	0	0.32±0.015^{fD}	0.44±0.015^{eD}	0.63±0.010^{cD}	0.69±0.010^{bD}	0.45±0.025^{eC}	0.62±0.010^{cC}	0.66±0.005^{bC}	0.59±0.015^{dD}	0.68±0.015^{bD}	0.77±0.015^{aD}
	1	0.47±0.015^{eC}	0.49±0.010^{eC}	0.66±0.20^{cC}	0.71±0.015^{bC}	0.50±0.040^{eC}	0.64±0.025^{cC}	0.66±0.040^{cC}	0.60±0.010^{cC}	0.71±0.010^{bC}	0.84±0.020^{aC}
	2	0.67±0.005^{eB}	0.68±0.005^{eB}	0.74±0.005^{dB}	0.85±0.010^{cB}	0.69±0.010^{eB}	0.72±0.025^{dB}	0.84±0.030^{cB}	0.73±0.005^{dB}	0.89±0.005^{bB}	0.94±0.015^{aB}
	3	0.76±0.010^{fA}	0.79±0.005^{eA}	0.87±0.020^{dA}	0.95±0.015^{bA}	0.82±0.020^{eA}	0.85±0.035^{dA}	0.91±0.040^{cA}	0.86±0.010^{dA}	0.95±0.005^{bA}	1.08±0.091^{aA}
Springiness (mm)	0	20.32±0.020^{aA}	20.29±0.010^{aA}	20.08±0.030^{bA}	19.99±0.100^{cA}	20.27±0.050^{aA}	20.05±0.040^{bcA}	19.98±0.010^{cA}	20.11±0.035^{bA}	19.84±0.025^{dA}	19.17±0.055^{eA}
	1	19.87±0.010^{aB}	19.82±0.030^{aB}	19.74±0.045^{bB}	19.60±0.045^{cB}	19.82±0.010^{aB}	19.71±0.045^{bB}	19.59±0.055^{cB}	19.57±0.045^{cB}	19.37±0.055^{dB}	18.88±0.035^{eB}
	2	19.31±0.010^{aC}	19.32±0.040^{aC}	19.29±0.025^{aC}	19.12±0.010^{bC}	19.28±0.025^{aC}	19.16±0.025^{bC}	19.12±0.015^{bC}	19.11±0.015^{bC}	18.96±0.020^{dC}	18.54±0.095^{eC}
	3	18.90±0.025^{aD}	18.88±0.035^{aD}	18.81±0.035^{aD}	18.54±0.090^{cD}	18.91±0.065^{aD}	18.65±0.110^{bD}	18.32±0.010^{dD}	18.58±0.055^{bcD}	18.26±0.055^{dD}	18.09±0.020^{eD}
Gumminess (N)	0	0.69±0.045^{eD}	0.97±0.025^{dD}	1.46±0.030^{cC}	1.78±0.040^{bC}	0.98±0.060^{dD}	1.41±0.060^{cC}	1.71±0.020^{bC}	1.43±0.035^{cC}	2.32±0.115^{aC}	2.34±0.035^{aC}
	1	1.03±0.015^{dC}	1.13±0.020^{dC}	1.55±0.120^{cC}	1.92±0.240^{bC}	1.17±0.020^{dC}	1.50±0.085^{cBC}	1.80±0.040^{bC}	1.58±0.055^{cC}	2.52±0.070^{aC}	2.64±0.025^{aC}
	2	1.60±0.025^{dB}	1.66±0.070^{dB}	2.24±0.030^{cB}	2.41±0.155^{cB}	1.73±0.130^{dB}	1.76±0.165^{dB}	2.78±0.200^{bB}	2.20±0.345^{cB}	3.28±0.410^{aB}	3.58±0.145^{aB}
	3	2.30±0.005^{eA}	2.42±0.110^{deA}	2.72±0.110^{dA}	3.07±0.115^{cA}	2.55±0.205^{deA}	2.68±0.225^{dA}	3.10±0.450^{cA}	3.13±0.080^{cA}	3.95±0.270^{bA}	4.53±0.305^{aA}
Chewiness (mJ)	0	2.21±0.010^{eD}	2.24±0.010^{eD}	2.33±0.025^{cdD}	2.40±0.005^{bD}	2.24±0.010^{eD}	2.32±0.010^{dD}	2.37±0.015^{bcD}	2.32±0.025^{dD}	2.51±0.020^{aD}	2.55±0.060^{aD}
	1	2.43±0.020^{eC}	2.44±0.025^{eC}	2.55±0.010^{dC}	2.61±0.040^{cC}	2.45±0.010^{eC}	2.55±0.020^{dC}	2.64±0.020^{cC}	2.51±0.025^{dC}	2.71±0.020^{bC}	2.84±0.010^{aC}
	2	2.27±0.020^{eB}	2.77±0.015^{eB}	2.87±0.020^{cdB}	2.89±0.020^{cB}	2.76±0.030^{eB}	2.89±0.010^{cB}	2.94±0.010^{bB}	2.83±0.005^{dB}	2.96±0.010^{bB}	3.05±0.060^{aB}
	3	2.94±0.015^{fA}	2.94±0.030^{fA}	3.07±0.005^{eA}	3.16±0.015^{dA}	2.96±0.010^{fA}	3.09±0.005^{eA}	3.21±0.010^{cA}	3.09±0.015^{eA}	3.28±0.010^{bA}	3.38±0.045^{aA}

* Means with the different small letters within the same row and means with different capital letters within the same column are significantly different ($P \leq 0.05$).
BRF: broken rice flour; BPF: broken pasta flour; BFBF: broken faba bean flour.

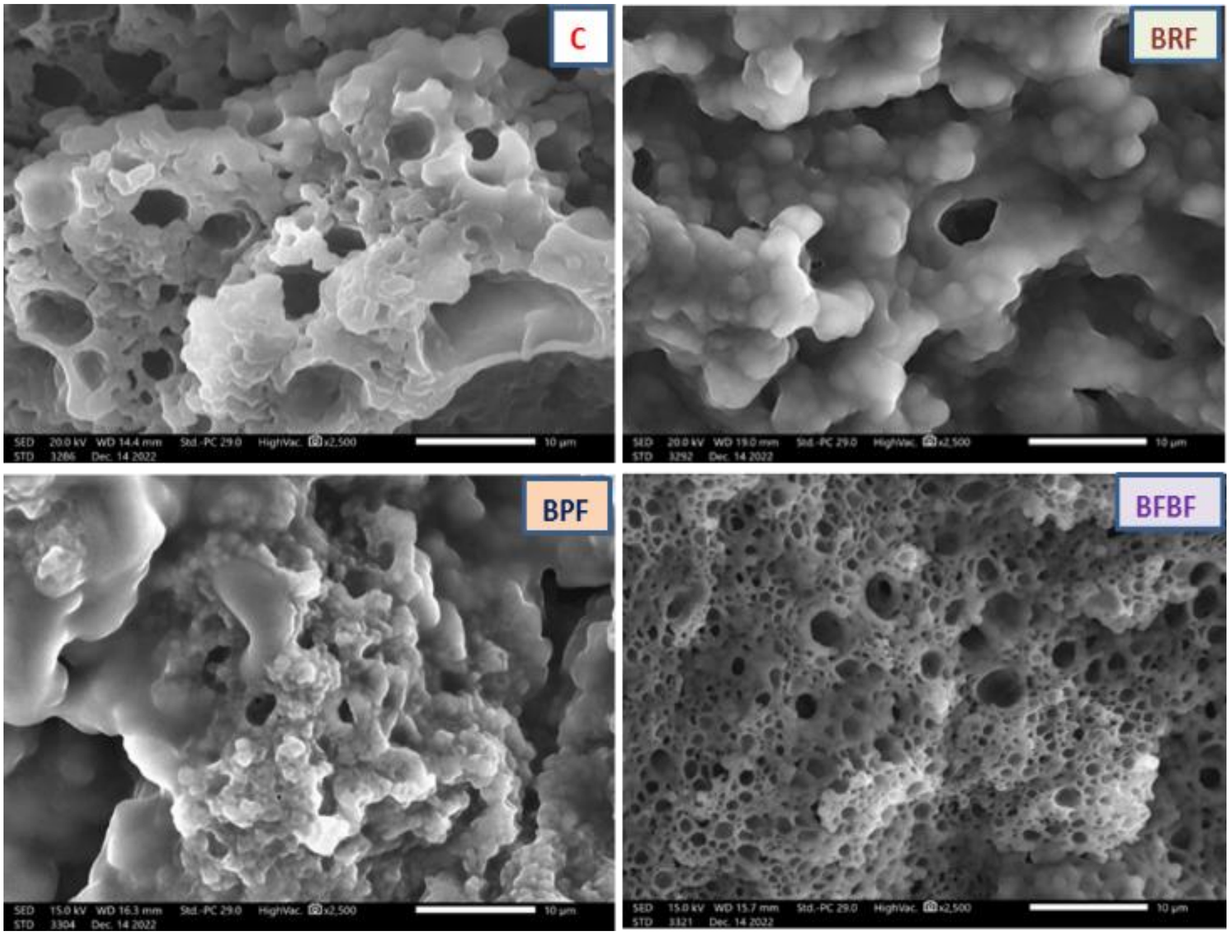
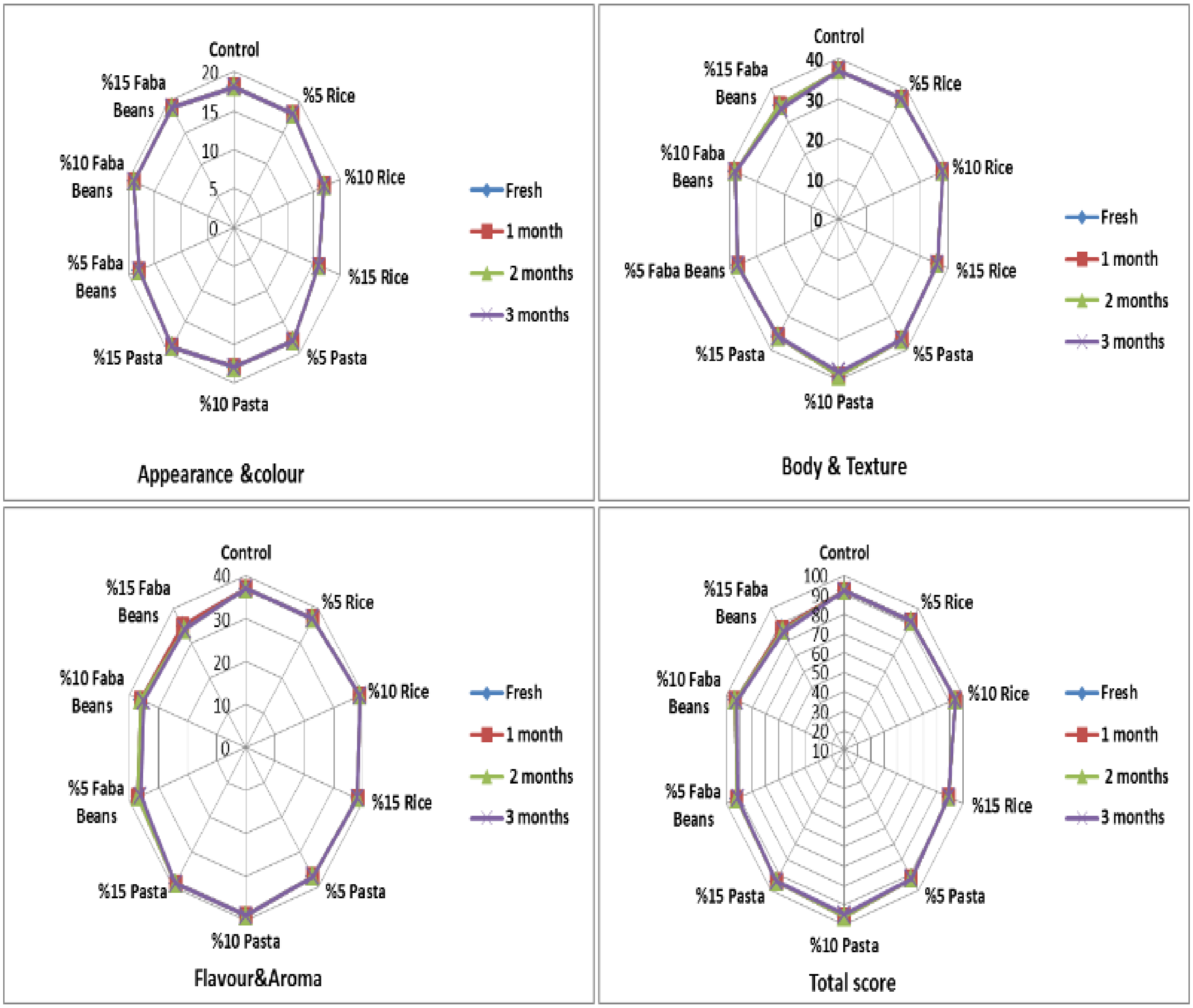


Figure 3. SEM image of microstructure of processed cheese. Control fresh processed cheese of young Ras and matured Cheddar cheeses as a base blend. C: Control; BRF: Processed cheese containing of 10 % broken rice flour; BPF: Processed cheese containing of 10 % broken pasta flour; BFBF: Processed cheese containing of 10 % broken faba bean flour.

Body and texture of fresh and stored PCS samples were no affected (P>0.05) by using all food wastes at level of 5%. Improvements in body and texture scores were recorded when all food waste was used at level of 10%. On the other hand, the body and texture properties were negatively affected for all samples of cheese produced using all food waste at the 15% level, recorded a score lower than the control PCS. There were no significant differences (P>0.05) in the appearance and color scores of the PCS samples from different treatments at level of 5%, and the control sample in fresh and stored cheese. The treated PCS with BFBF and BPF had the highest scores for appearance and colour being 19 out of 20 points at level of 10% and 15%, this was true in fresh and during storage period. Whereas the minimum points were given for the BRF treated PCS samples. The use of the BRF negatively (P≤0.05) affected the appearance and colour of cheese at levels above 5% and this was true both in fresh and also during three months of cold storage.

Figure 4. Organoleptic properties of processed cheese spreads made with different ratios of BRF, BPF, and BFBF during cold storage for 3 months.



4. Conclusion

Finally, this study cleared that processed cheese can be manufactured by replacing natural cheese in the processed cheese formula with BRF, BPF, and BFBF at ratios of 5 and 10 %. The utilization of BRF, BPF, and BFBF in the preparation of PCS caused significant changes in the physicochemical, textural, and microstructural properties of the final product. An addition ratio of 15% reduced the acceptability of some sensory properties in the resulting cheese, with the exception of BPF. This study recommended the use of BRF, BPF, and BFBF in the preparation of PCS at a ratio of 10 %. The decrease in the amount of natural cheese used in making processed cheese will in turn decrease the cost of production. This is quite important from an economic point of view. Moreover, the use of food industry waste in new products offers numerous benefits in terms of resource conservation, innovation, and consumer acceptance. By adopting these practices, the food industry can contribute significantly to achieving the Sustainable Development Goals.

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