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Functional low-fat labneh fortified with resistant potato starch as prebiotic and assessed physicochemical, microbiological, and sensory properties during storage

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Abstract

Resistant Potato Starch (RPS) is a fundamental prebiotic used in dairy products. The study aims to evaluate the role of RPS as a fat substitute in the production of Labneh cheese. RPS1, RPS2, and RPS3 labneh treatments were prepared using 0.5, 1, and 1.5% of RPS, compared to modified buffalo milk full-fat control labneh (FBC) 4% fat, and low-fat control labneh (LBC) 2% fat. The physicochemical, microbiological, and sensory characteristics of labneh were investigated after 29 days of storage. The results demonstrated that RPS2 and RPS3 had remarkable significant differences ($P > 0.0001$) in physicochemical and sensory properties. As a consequence, we recommend that RPS may be used in the manufacturing of functional labneh.

Keywords: Low-fat Labneh, resistant potato starch, Fat mimetics Microstructure, prebiotic.

1. Introduction

Functional foods, which provide health advantages in addition to basic nutrition and/or minimize the risk of chronic diseases, are now given a lot of attention. One of the most often utilized ingredients in functional foods is resistant starch (RS), which is classified as a form of dietary fiber [21]. The percentage of starch that escapes digestion in the small intestine and can thus be fermented in the colon is known as resistant starch. (RS) [13].

Consumers are encouraged to consume low-fat or fat-free meals in balance and to moderate their consumption of full-fat dairy products due to their high saturated fatty acid content [23]. Hence, Labneh is a popular semi-solid fermented dairy product in the Middle East. It is typically prepared by draining off part of the water and water-soluble components from previously manufactured yoghurt and concentrating the solid particles with lactic acid bacterial strains. Also, it has a white appearance, a creamy and smooth texture, excellent spreadability, mild syneresis, and a clean, slightly acidic flavor. Its total solid content normally ranges between 23 – 25g/100g, with fat contributing in 8 – 11g/100g of Labneh [26].

Resistant starch or modified starch is composed of dietary fiber starch and its breakdown products that are not completely digested or absorbed in the small intestines of healthy individuals but are totally or partially fermented in the colon. Also, it has been demonstrated to offer potential health benefits such as lowering blood cholesterol, acting as a functional prebiotic, and encouraging the synthesis of short-chain fatty acids in the large intestine [9].

Compared with other vegetable starches, potato starch has the highest maximum stickiness and, the most transparent porridge properties. Due to these properties, it is widely used in the food industry. As a result, it is vital to evaluate changes in the gelling properties of resistance potato starch [15]. There are several ongoing initiatives to lower the fat content of diets without affecting their flavor or texture. Moreover, various studies have employed carbohydrate-based components such as inulin, dextrin, maltodextrins, and modified starches to enhance the viscosity, texture, and stability of certain products such as low-fat yoghurt [37].

Prebiotics are dietary components found in a wide range of fruits and vegetables. It is employed as

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a vital stabilizer in manufactured dairy products like yogurt because it improves organoleptic properties such as flavor, ideal viscosity, and texture. It also improves foam, emulsion, and mouthfeel stability [4]. Furthermore, inhibiting/reducing syneresis during storage and transportation raises the ratio of the total solid, and controls flavor and aroma release [34].

Starches such as maize, sweet potato, potato, and chestnut are often used in yogurt production at 0.25 to 1%. "They are popular in the yogurt market because they are an effective thickening and may reduce defects in yogurt by improving texture and making the product more appealing to customers [42].

This study aims to investigate the production of functional low-fat yoghurt cheese called "Labneh" and the effect of resistant potato starch as a fat substitute on chemical, physical, rheological, microstructure, and sensory properties during storage.

2. Experimental

1.1. Materials

The standard whole buffalo milk used in the production of Labneh included (82.76% water; 7.38% fat; 3.60% protein; 5.48% lactose and 0.78% ash) from EL-Gemmeza Station Animal Production Research Institute, Egypt. Resistance potato starch (RPS) and other chemicals were obtained from (Sigma, USA). Furthermore, Oxide provides all of the media and supplements utilized in microbiological analysis (Oxide, England). All solutions were prepared using distilled water, and Pyrex glassware was used throughout. Yoghurt starter cultures ((*Streptococcus salivarius* subsp. *thermophilus* + *Lactobacillus delbrueckii* subsp. *bulgaricus*) were purchased from (Chr. Hansen's Laboratories, Denmark).

2.1. Preparation of low-fat Labneh

The fat content of fresh full-fat buffalo milk was adjusted using fresh skimmed buffalo milk to become 4% fat (FBC), while the other four treatments reduced the fat percentage to 2%. One of them was the low-fat control (LBC), while the other three treatments added 0.5, 1, and 1.5% resistance potato starch RPS_1, RPS_2, and RPS_3, respectively.

Tamime and Robinson[35] previously described with a few modifications. For 15 min, each treatment was heated to 90°C. The milk was then chilled to 42°C before being inoculated with yoghurt culture of 3% at 42°C until gel formed. The yoghurt was held at 4°C overnight before being placed in cotton bags and hung in a refrigerator for 24h to allow for whey drainage. The resultant Labneh was combined with sodium chloride (1% w/w) packed into 250g plastic cups, wrapped in polyethylene film, and kept at 5°C for 29 days.

2.3.Physicochemical analysis

All physicochemical characteristics of milk and Labneh samples were evaluated using procedures approved by the Association of Official Analytical Chemists [5]. Moisture % was determined in a Turbofan oven (Bakbar Versatile Bench Top Model E32, Germany) at 105°C for 3h, fiber (using crude fiber apparatus unit), fat, and protein content were calculated using the Gerber and Kjeldahl techniques, respectively, and pH was measured using an electrode pH-meter (Hanna, Germany). The acidity was represented as a percentage of lactic acid and was evaluated by titrating the endpoint with 0.5% phenolphthalein indicator of diluted Labneh cheese solution using a NaOH (0.9 N). Carbs% was determent as a difference between protein; fat; fiber; ash, and moisture%. Acetaldehyde and diacetyl were determined according to the method [40].

2.4. The protein and fat losses in different treatments of low-fat Labneh

The loss of protein and recovery of protein content in different treatments were calculated by EL-Dardiry [11]. The loss of fat and recovery of fat content in different treatments were calculated by EL-Dardiry [11]. The yield of low-fat labneh in different treatments were calculated by Fox [12].

2.5. Microbiological Analysis of low-fat Labneh cheese

The standard plate count method was used to determine the number of potential probiotics. Ten grams of Labneh were blended for one minute in 90 mL of sterile peptone water using an electromechanical homogenizer (Stomacher Lab-blender 400; Seward Medical, London, UK).

Streptococcus salivarius subsp. *thermophilus* was counted using M17 (Oxoid, UK) supplemented with 1.5% bacteriological agar (Merck, UK) and incubated aerobically at 42 – 45°C for 72h, whereas *Lactobacillus delbrueckii* subsp. *bulgaricus* was counted on MRS (Oxoid, UK) and incubated anaerobically at 42–45°C for 72h, and a total count was performed using nutrient agar (Oxoid, UK) at 40 – 42°C for 48h. Mold and yeast were determined according to (Ryu and Wolf-Hall 2015). All experiments were carried out in triplicate and the results were expressed as log CFU /ml.

2.6. Water Holding Capacity(WHC)and Syneresis of low-fat Labneh cheese

Water holding capacity (WHC) and syneresis analysis were determined by the method [25]. Samples of fermented milk (about 20 g) (Y) after cooling to +4 ° C in 24 hours of storage were centrifuged for 10 minutes at 3000 rpm, +20°C. The released serum (W) was removed and weighed. The Water-holding capacity of fermented milk is calculated by the followed formula:

WHC% = Y - W / Y x 100

Syneresis was measured after samples (about 20 g) were cooled to +4°C in 24 hours of storage (Y). Samples were centrifuged for 5 minutes, 500 rpm at + 20°C. The released serum (S) was removed and weighed. Syneresis of fermented milk is calculated by the formula:

Syn = S / Y.

The results are expressed in grams of water/100 g of the Labneh.

2.7.Texture profile analysis (TPA) :

The texture profile of labneh was investigated using a TA-XT texture analyzer (CNS-Farnell, Borehamwood, Hertfordshire,185 UK), as reported by [18]. During the 29 days of storage, all treated samples were exposed to a deformation force equal to 25% of their weight. The sample of labneh was filled to the 3.5 cm height of the sample container (50 ml capacity, 5.5 cm height, 4 cm internal diameter) constructed of high-density polyethylene, and analyzed for textural features and was kept at room temperature for one hour before beginning the assay under conditions P/0.5 probe, test speed 1.0 mm/sec, while the test speed before and after 5.0 mm/sec, the time between first and second pressed 5.0 sec, compression ratio 30 %, and two compression cycles. Gumminess is calculated from hardness X cohesiveness. Moreover, chewiness is calculated from hardness X cohesiveness X springiness.

2.8. Microstructure of Labneh

Cryo-Scanning Electron Microscopy (Cryo SEM) was used to analyze the microstructure of Labneh samples at a high vacuum (model JSM6100JEOL Ltd, Akishima, Japan). Labneh samples (1×1×5 mm) were cut out and put on a cryostat sample holder before being gold-plated. Each treatment is shown by a representative micrograph obtained at 1000 magnification [36].

2.9. Sensory Evaluation of low-fat Labneh cheese

The sensory properties of Labneh were examined by 16 experts (8 males and 8 females, aged 30 to 55). All of the participants affirmed that they had no dairy allergies or other health issues. Additionally, sensory experts were chosen the following International Organization for Standardization ISO 8586:2012. [14]. Each sensory aspect of each Labneh sample, such as appearance (10), body and texture (30), flavor (60), and overall acceptability (100), was assessed as a point deducted from the total score of each evaluation [27]. To avoid interference between the sensory evaluation of each sample for the tastes of the panelists while providing drinking water to ensure no sensory disturbance, there was a three main interval between each sample's evaluation.

2.10. Statistical Analysis

All results were given as Mean±SD. The statistical significance of data comparisons was established using a two-way analysis of variance (ANOVA). Statistical analysis was performed using [32] system software (version 9.1, SAS Institute, Cary, NC, USA) to compute F values and compare means using Duncan's multiple range test. GraphPad Prism was used to create graphs (version 8.1 GraphPad).

3.Results and Discussion

The addition of resistant- potato starch (RPS) to Labneh resulted in substantial variations (P<0.0001) in moisture and fiber content, as shown in Table 1. The RPS_3 treatment had the highest moisture level 79.81±9.24% and 77.93±4.11% respectively, whereas the full-fat control FBC treatment had the lowest moisture content 74.47±7.02% and 70.62±4.32% respectively both in the fresh treatments and after four weeks of storage. Resistant-potato starch (RPS) addition lowered the overall composition of Labneh fortified with RPS in protein, fat, and ash, with significant variations across treatments (P<0.0001). While there were significant differences (P<0.0001) in each of the moisture content, carbs, salt, and ash with increasing storage periods of up to 29 days. Besides, there were no significant differences during the storage period on the content of Labneh's chemical composition. In Table 1. The results agreed with those of Mehanna et al. [20], who indicated that the conventional and direct formulation methods used to manufacture probiotic Labneh from skim milk powder had the lowest carbohydrate content and acidity. Also, the results were similar to Nikitina, et al. [24].

Evaluation of the starter culture activity during coagulation time

Using changes in the acidity of low-fat Labneh over the incubation time, the analysis indicates that the acidity% of the RPS treatments increased quicker than the control groups. There were no significant variations in acidity amongst Labneh treatments (P < 0.0001). The activity of the yoghurt starter culture is evaluated in Table 2.

Table 1. Chemical composition (Mean±SD) of low-fat Labneh fortified with different levels of RPS during the storage.

Storage/days	FBC	LBC	RPS_1	RPS_2	RPS_3
			Moisture %		
1	74.47±7.02^{Ea}	76.63±10.92^{Da}	77.24±1.57^{Ca}	78.02±1.52^{Ba}	79.81±9.24^{Aa}
8	73.49±6.56^{Eab}	75.58±1.15^{Dab}	76.74±6.80^{Cab}	77.53±4.38^{Bab}	79.24±2.21^{Aab}
15	72.46±5.99^{Ebc}	74.58±9.44^{Dbc}	76.01±3.44^{Cbc}	76.84±3.51^{Bbc}	78.83±3.01^{Abc}
22	71.52±1.53^{Ec}	73.43±1.03^{Dc}	75.44±2.96^{Cc}	76.28±2.73^{Bc}	78.30±1.11^{Ac}
29	70.62±4.32^{Ed}	72.40±6.03^{Dd}	74.51±5.23^{Cd}	75.69±4.73^{Bd}	77.93±4.11^{Ad}
			Fat %		
1	11.0±0.63^{Aa}	8.40±0.03^{Ba}	7.66±0.07^{Ca}	6.73±0.14^{Da}	6.55±0.11^{Da}
8	11.13±0.53 ^{Aa}	8.55±0.50^{Ba}	7.73±0.06^{Ca}	6.77±0.07^{Da}	6.60±0.10^{Da}
15	11.15±0.41^{Aa}	8.55±0.50^{Ba}	7.73±0.05^{Ca}	6.78±0.04^{Da}	6.60±0.01^{Da}
22	11.10±0.72^{Aa}	8.50±0.59^{Ba}	7.70±0.08^{Ca}	6.75±0.37^{Da}	6.58±0.04^{Da}
29	11.0±0.63^{Aa}	8.46±0.38^{Ba}	7.68±0.07^{Ca}	6.74±0.00^{Da}	6.55±0.04^{Da}
			Protein %		
1	11.54±0.35 ^{Ba}	12.01±2.95^{Aa}	10.83±2.32^{Ca}	10.74±0.20^{Da}	10.31±0.34^{Ea}
8	11.59±1.13^{Bc}	12.07±0.69^{Ac}	10.87±0.82^{Cc}	10.78±0.04^{Dc}	10.34±0.59^{Ea}
15	11.68±0.27^{Bab}	12.20±0.17^{Aab}	10.95±0.73^{Cab}	10.87±0.44^{Dab}	10.42±0.32^{Eab}
22	11.65±1.27^{Babc}	12.17±0.59^{Aabc}	10.93±0.61^{Cabc}	10.84±0.02^{Dabc}	10.39±0.53^{Eab}
29	11.63±0.63^{Bbc}	12.12±0.40^{Abc}	10.90±0.50^{Cbc}	10.80±0.12^{Dbc}	10.36±1.68^{Ebc}
			Ash %		
1	0.994±1.15^{Ad}	0.983±1.10^{BCd}	0.992±1.27^{Ad}	0.987±1.24^{Bd}	0.979±1.15^{Cd}
8	0.994±1.16^{Acd}	0.986±1.13^{BCcd}	0.994±1.01^{Acd}	0.988±1.13^{Bcd}	0.983 ±1.27 ^{Ccd}
15	0.995±0.58^{Abc}	0.990±0.55^{BCdc}	0.995±0.46^{Abc}	0.990±0.59^{Bbc}	0.989±0.55^{Cbc}
22	0.995±0.62^{Ab}	0.992±0.24^{BCb}	0.998±0.26^{Ab}	0.994±0.32^{Bb}	0.992 ±0.58^{Cb}
29	0.979±1.15^{Cd}	0.995±1.27^{BCa}	1.01±0.55^{Aa}	0.999±0.58^{Ba}	0.997±0.58^{Ca}
			Salt %		
1	1.60±0.56^{Ac}	1.50±0.41^{Ac}	1.40±0.62^{Bc}	1.30±0.17^{Bc}	1.30±1.32^{Bc}
8	1.80±0.41^{Ab}	1.70±0.17^{Ab}	1.60±0.18^{Bb}	1. 50±0.03^{Bb}	1.50±0.09^{Bb}
15	2.00±0.43^{Ab}	1.90±0.03^{Ab}	1.75±0.23^{Bb}	1.65±0.35^{Bb}	1.60±0.50^{Bb}
22	2.20±0.46^{Aa}	2.30±1.20^{Aa}	1.90±1.16^{Ba}	1.80±0.82^{Ba}	1.80±1.20^{Ba}
29	2.30±0.59^{Aa}	2.40±0.20^{Aa}	2.10±0.03^{Ba}	1.95±0.41^{Ba}	1.90±0.03^{Ba}
			Fiber %		
1	ND	ND	0.16±0.38^{Ca}	0.28±0.01^{Ba}	0.42±2.46^{Aa}
8	ND	ND	0.17±0.41^{Ca}	0.30±0.21^{Ba}	0.42±0.31^{Aa}
15	ND	ND	0.17±0.14^{Ca}	0.31±2.03^{Ba}	0.44±0.47^{Aa}
22	ND	ND	0.18±0.61^{Ca}	0.31±0.05^{Ba}	0.45±0.26^{Aa}
29	ND	ND	0.19±0.11^{Ca}	0.32±0.03^{Ba}	0.45±0.11^{Aa}
			Carbs %		
1	0.396±0.21^{De}	0.477±0.14^{Ce}	1.718±0.11^{Be}	1.943±0.13^{Ae}	0.631±0.31^{Ee}
8	1.12±3.11^{Dd}	1.204±0.31^{Cd}	1.946±0.14^{Bd}	3.162±0.71^{Ad}	0.967±0.21^{Ed}
15	1.815±0.15^{Dc}	1.91±0.13^{Cc}	2.475±0.21^{Bc}	3.66±0.55^{Ac}	1.201±0.11^{Ec}
22	2.505±0.24^{Db}	2.558±2.11^{Cb}	2.82±2.11^{Bb}	4.006±0.18^{Ab}	1.468±1.41^{Eb}
29	3.253±0.51^{Da}	3.455±0.51^{Ca}	3.51±0.16^{Ba}	4.391±0.11^{Aa}	1.703±3.34^{Ea}

FBC, Full-fat Labneh cheese control ; LBC,Low-Fat Labneh cheese control; RPS_1, Low-Fat Labneh (0.5% resistant potato starch); RPS_2, Low-Fat Labneh (1.0% resistant potato starch); RPS_3, Low-fat Labneh (1.5% resistant potato starch). A, B, C,....: Means for each treatment with the same letter in the same character are not statistically different ($P<0.0001$). a,b,c,d: Means of treatments in the same storage period with the same letter in the same character are not significantly different ($P<0.0001$). ND: Not detected

The results revealed that adding RPS at 1.5 or 1% reduced the coagulation time to 60 min, whereas adding 0.5% raised the coagulation time to 90 min. On the other hand, the LBC was coagulated after 150 min, and FBC was coagulated after 120 min. Table 2. the acceleration of the occurrence of cheese in the treatments fortified with RPS is expected due to the growth of microorganisms cultured in the initiator that is incubated in milk. The growth of the starter microorganisms was lower in the up-regulated permeability control treatments compared to the other treatments. This may be due to the presence of RPS which may act as a prebiotic and stimulate the growth of initiating microorganisms[10]. Prasad et al. [28] who say prebiotics are utilized to promote the survival of probiotics. Prebiotics are no digestible carbohydrates that are not absorbed in the intestine, such as modified starch, which stimulates the activity of cultured yoghurt. Also, It explains FBC coagulated faster than LBC This may be because increased solids in milk for the FBC treatment speed up incubation.

Table 2. Estimation of acidity % of low-fat labneh fortified with different levels of RPS during the incubation period/min.

Incubation time/ min	Treatments				
	FBC	LBC	RPS_1	RPS_2	RPS_3
0.0	0.25	0.27	0.31±0.71	0.35±0.06	0.42±0.03
30	0.34	0.47	0.60±0.78	0.87±0.03	0.90±0.02
60	0.42	0.46	0.95±0.21	coagulated	coagulated
90	0.64	0.71	coagulated	coagulated	coagulated
120	coagulated	0.98	coagulated	coagulated	coagulated
150	coagulated	coagulated	coagulated	coagulated	coagulated

See details Table 1

Loss and recovery of protein or fat of low-fat Labneh

Table 3 depicted the protein and fat loss or recovery% in Labneh enhanced with resistant-potato starch. The results showed that adding PRS to low-fat Labneh cheese resulted in a substantial ($P < 0.01$) decrease in the losses of protein or fat%. RPS_3 had the lowest protein and fat content decreases, at 7.41±0.16% and 0.20±0.08% respectively, whereas FBC was 16.11±0.08% and 2.13±0.02% respectively. That could be due to the dietary fiber and starch which had desirable functional properties, such as improving gelling, thickening texture, stabilization and emulsification [11], [22]. The starch may trap protein and fat in the cheese curd and reduce their descent into whey [33].

Table 3. Loss and recovery of protein and fat in low-fat Labneh fortified with different levels of RPS.

Properties	Treatments				
	FBC	LBC	RPS_1	RPS_2	RPS_3
Protein loss %	16.11±0.08 ^{B}	17.01±0.11 ^{A}	14.27±0.03 ^{C}	11.05±0.19 ^{D}	7.41± 0.16 ^{E}
Recovery of protein%	83.89±0.08 ^{D}	82.99±0.11 ^{D}	85.73±0.03 ^{C}	88.95±0.19 ^{B}	91.36±0.16 ^{A}
Fat loss%	2.13±0.02 ^{A}	1.91±0.04 ^{B}	1.42±0.12 ^{C}	0.75±0.07 ^{D}	0.20±0.08 ^{E}
Recovery of fat%	97.87±0.02 ^{D}	98.09±0.04 ^{D}	98.68±0.12 ^{C}	99.25±0.07	99.80±0.08 ^{A}

See details Table 1

The yield% of low-fat Labneh cheese

The yield % of low-fat labneh cheese samples fortified with different levels of RPS are presented in Table (4). The yield of different treatments for low-fat labneh cheese-fortified RPS was higher than the control cheese. Control labneh cheese made from low-fat buffalo was the lowest value. It was noted in Table 4 that RPS_3 led to an increase in the clarification of cheese by 26.66 compared to the full-fat labneh control, while the increase was 54.21 compared to the low-fat control. That was due to the solids content in low-fat buffalo milk cheese compared with full-fat buffalo milk cheese. That which is agreed with Ayyad, et al. [6]. There were significant differences ($P<0.0001$) between labneh cheese treatments. Also, the addition of RPS led to an increased yield % These results were similar to El-Dardiry, Sit, et al. [11], [33] indicated that starch can retain protein and fat in the cheese curd and reduce their descent into the whey, which can be attributed to the desired functional properties of gelling, thickening texture, stability, and emulsification. Furthermore, the results were consistent with the finding of Kebeya et al. [16] who indicated that the inclusion of RPS resulted in a higher yield% of mozzarella cheese. Additionally Chakravarty, et al. [8] reported that the inclusion of RPS, which functions as a prebiotic agent, increased the survivability of *Lactobacillus paracasei* CD4 for up to two weeks under refrigeration in a synbiotic fermented milk preparation.

Table 4. Yield % and Increament of yield of low-fat Labneh fortified with different levels of RPS.

Properties	Treatments				
	FBC	LBC	RPS_1	RPS_2	RPS_3
Yield%	31.24 ±0.17^{D}	25.66 ±0.10^{E}	34.33± 0.2^{C}	38.61± 0.13^{B}	39.57± 0.16^{A}
Increment% with C_1	-	-	9.89	23.59	26.66
Increment% with C_2	17.86	-	33.79	50.47	54.21

See details Table 1

PH value and Acidity % of low-fat Labneh cheese

Table 5 shows the fluctuations in acidity and pH of labneh, the acidity and pH of labneh treatments did not vary significantly (p<0.0001). The obtained results displayed that PRS_3 had the highest acidity percentage even at zero time and after 29 days of storage, gaining 0.76±0.11% at zero time and gradually increasing to reach 1.63±0.04 % after 29 days of storage, compared to FBC, which gained the lowest acidity values in both zero and after 29 days of storage, achieving 0.38±0.23 and 1.01±0.53% respectively. Also, the results in table 5 showed the same line of acidity as the pH values. When compared to FBC, the pH of PRS_3 decreased from 5.14±0.24 at zero time to 4.58±0.13 after 29 days of storage. whereas the pH of FBC dropped from 5.61±0.02 to 5.16±1.32 respectively. The results were consistent with those of Abdel–Salam et al. [2] and Abbas, et al. [1], who investigated higher acidity in treatments during storage, which could be attributed to the growth and activity of Labneh bacterial strains that converted lactose to lactic acid. The results in Table 6 are due to the added modified starch stimulating the activity of the initiator bacteria, which worked to produce the flavor [10], [41].

Table 5. Change of pH and Acidity % of low-fat labneh fortified with different levels of RPS during the storage

Storage /days	FBC	LBC	RPS_1	RPS_2	RPS_3
			pH		
1	5.61±0.02^{Aa}	5.66±0.92^{Aa}	5.43±1.57^{Ba}	5.2±0.52^{BCa}	5.14±0.24^{Ca}
8	5.49±0.56^{Aab}	5.52±0.15^{Aab}	5.26±6.80^{Bab}	5.18±0.38^{BCab}	5.05±0.21^{Cab}
15	5.38±0.99^{Abc}	5.46±0.44^{Abc}	5.08±3.44^{Bbc}	5.02±0.51^{BCbc}	4.92±0.31^{Cbc}
22	5.19±1.53^{Acd}	5. 34±1.03^{Acd}	5.00±2.96^{Bcd}	4.86±0.73^{BCcd}	4.76±1.01^{Ccd}
29	5.16±1.32^{Ad}	5.21±0.03^{Ad}	4.89±5.23^{Bd}	4.72±0.73^{BCd}	4.58±0.13^{Cd}
			Acidity %		
1	0.38±0.23^{Aa}	0.46±0.03^{Aa}	0.57 ±0.07^{Aa}	0.65±0.16^{Aa}	0.76±0.11^{Aa}
8	0.73±0.33^{Aa}	0.76±0.50^{Aa}	0.78 ±0.06^{Aa}	0.95±0.07^{Aa}	1.01±0.10^{Aa}
15	0.79±0.1^{Aa}	0.83±0.50^{Aa}	0.97 ±0.05^{Aa}	1.13±0.04^{Aa}	1.21±0.01^{Aa}
22	0.93±0.42^{Aa}	0.98±0.59^{Aa}	1.05 ±0.08^{Aa}	1.27±0.47^{Aa}	1.35±0.04^{Aa}
29	1.01±0.53^{Aa}	1.07±0.38^{Aa}	1.18 ±0.07^{Aa}	1.42±0.20^{Aa}	1.63±0.04^{Aa}

See details Table 1

Evaluation of acetaldehyde and diacetyl (mmol/100g) contents of Labneh cheese fortified with RPS

The principal aroma chemicals generated by the starter cultures are acetaldehyde and diacetyl, which lend a unique flavor to fermented milk such as labneh. The acetaldehyde content of labneh was greater than the developed diacetyl content, and the acetaldehyde to diacetyl ratio remained nearly constant throughout storage. The variations in acetaldehyde content between treatments were significant changes (p<0.0001). Table 6 demonstrates the acetaldehyde and diacetyl concentrations of several labneh samples when fresh and after 29 days of storage. The acetaldehyde and diacetyl content in labneh were affected by the addition of RPS, where the increase in acetaldehyde content was direct with the increase in RPS addition, whereas it was vice versa in the two control treatments that showed lower acetaldehyde content, either at zero time or after 29 days of storage. Both acetaldehyde and diacetyl contents were elevated to their maximum levels until 15 days of storage and subsequently dropped until the end of the storage period of 29 days in all treatments. It is evident that RPS3 had greater values of acetaldehyde and diacetyl 290±10.24 and 122±7.11 mmol respectively during the fresh time. These results are due to the added modified starch stimulating the activity of the initiator bacteria, which worked to produce the flavor Cos,kun, [10]. Also, acetaldehyde and diacetyl acquired 384 ±9.31 and 149±12.01 mmol after 15 days of storage, which subsequently decreased to 342±8.13 and 145±13.32 mmol respectively after 29 days of storage. On the other hand, LBC obtained the lowest values when compared to other groups at the same time.

Table 6. Evaluation of acetaldehyde and diacetyl (mmol/100 g) contents of low-fat labneh fortified with different levels of RPS during the storage

Storage /days	FBC	LBC	RPS_1	RPS_2	RPS_3
Acetaldehyde (mmol/ 100 g)					
1	274±7.61^{Cc}	258 ±5.66^{Cc}	269±5.43^{Cc}	281±9.2^{Bc}	290±10.24^{Ac}
8	293±10.49^{Cbc}	270±7.52^{Cbc}	290±6.80^{Cbc}	308 ±12.18^{Bbc}	321±5.21^{Abc}
15	307±13.38^{Cab}	296 ±5.46^{Cab}	301±5.08^{Cab}	363±15.02^{Bab}	384 ±9.31^{Aab}
22	278±6.19^{Ca}	269 ±8.34^{Ca}	288±2.96^{Ca}	339±14.86^{Ba}	370 ±76.01^{Aa}
29	227±5.16^{Cc}	218 ±4.21^{Cc}	245±5.23^{Cc}	324±10.72^{Bc}	342±8.13^{Ac}
Diacetyl (mmol/ 100 g)					
1	116±5.38^{Aa}	101±6.03^{Aa}	109±5.07^{Aa}	119±6.16^{Aa}	122±7.11^{Aa}
8	127±7.30^{Aa}	119 ±7.50^{Aa}	123±8.6^{Aa}	131±9.07^{Aa}	136±10.10^{Aa}
15	137±9.1^{Aa}	128±8.50^{Aa}	138±9.05^{Aa}	145±11.30^{Aa}	149±12.01^{Aa}
22	134±9.42^{Aa}	126±9.59^{Aa}	136±5.05^{Aa}	143±12.70^{Aa}	148±13.04^{Aa}
29	130±10.53^{Aa}	123±7.38^{Aa}	134±8.07^{Aa}	142±14.20^{Aa}	145±13.32^{Aa}

See details Table 1.

Microbiological assessment (log CFU/ mL) of Labneh cheese fortified with RPS

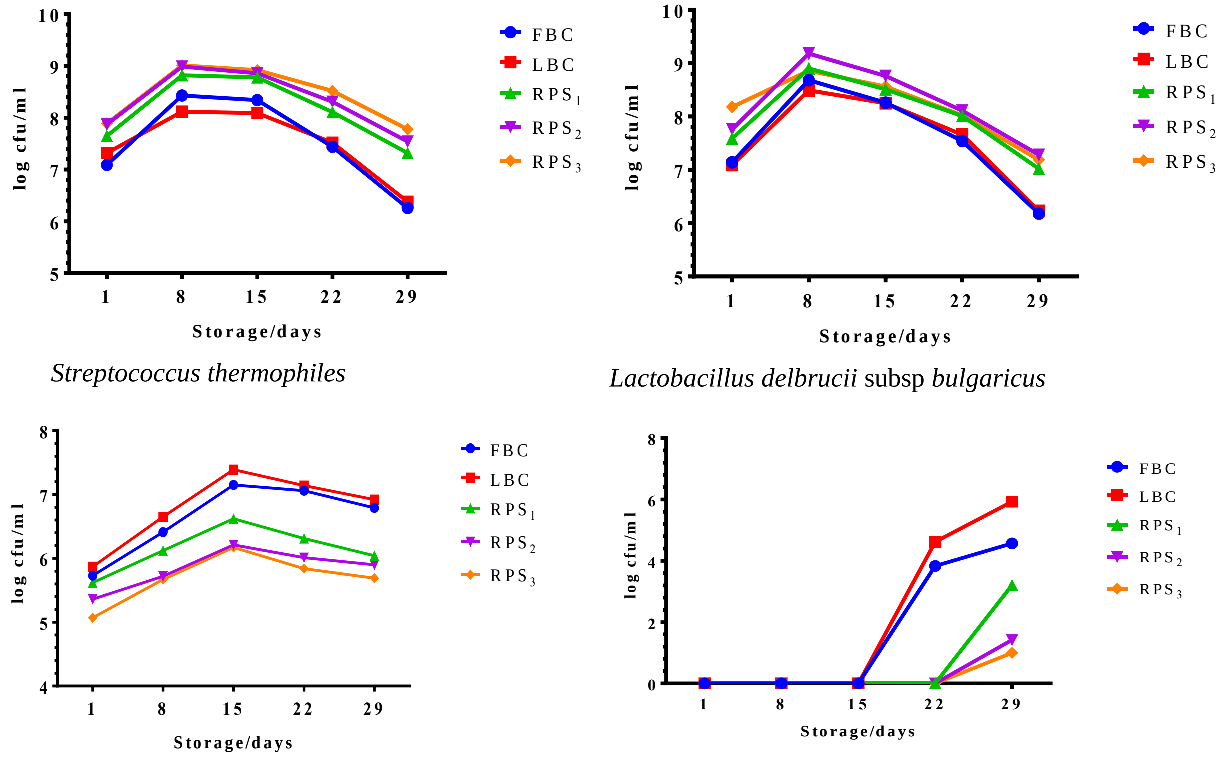
Figure 1 depicts the strain counts of <u>*Streptococcus salivarius*</u> subsp. *thermophilus* and *Lactobacillus delbrucii* subsp *bulgaricus,* as well as the total count, which showed significant variations (p<0.0001). The two strains had the greatest growth in the first and second weeks of storage and then gradually declined at the end of storage for all Labneh treatments. *Streptococcus salivarius* subsp *thermophilus* of RPS_3 was around (7.89±2.27 and 7.78±1.57) log CFU/ mL whereas FBC was about (7.09±1.98 and 6.26±0.63) log CFU / mL. Besides, *Lactobacillus delbrucii* subsp *bulgaricus* of RPS_3 (8.18±2.33 and 7.19±2.07) log CFU / mL compared with FBC which around (7.14±2.12 and 6.18±0.96) log CFU/ mL in both of zero time and after four weeks of storage. When compared to LBC, the total bacterial count of RPS_3 was roughly 5.07±0.74 and 5.69±1.87 log CFU /ml, On the other hand, Mold and yeast counts appeared after three weeks in control treatments but after four weeks in low-fat Labneh enhanced with RPS. LBC had the greatest total of Mold and yeast counts 5.93±1.45 log CFU /ml, while RPS_3 had the lowest total of 1.02±1.22 log CFU /ml.

The counts of lactic acid bacteria decreased gradually during the storage period. No coliform bacteria was detected in any of the yoghurt samples.

Figure 1 shows the total viable bacterial count increased until 15 days, then decreased until the end of the storage period of 29 days. The results were consistent with Çakmakçi, et al. [7] who reported that during the storage period, the rise was mirrored in banana marmalade yoghurts containing *Lactobacillus acidophilus*; <u>*Streptococcus salivarius*</u> subsp.*thermophilus* and *Bifidobacterium bifidum* counts had declined after two weeks, while *Lactobacillus delbrucii bulgaricus* counts had increased. This reduction was comparable to that reported in banana marmalade yoghurts containing *Bifidobacterium bifidum*. Similarly, as the obtained results the counts of *Lactobacillus acidophilus* and *Lactobacillus delbrucii* subsp *bulgaricus* dropped after two weeks. While the yeast and mold did not detect even during the last week of storage. Also, these results confirm what the Coşkun [10] proved that RPS acted as a prebiotic for the growth of culture starter. The results of TBC are similar to those of Şahan, et al. [30], who report that the total aerobic bacterial counts decreased during the storage.

Water holding capacity (WHC %) and syneresis (g of /100g labneh) low-fat labneh cheese

The WHC of Labneh is defined as its ability to preserve or retain some of its water. Both WHC% and syneresis have an inverse relationship, as seen in Figure 2, where it was significantly reduced (P<0.0001) in syneresis during storage and with the addition of RPS. Vice versa, compared to FBC and LBC, Labneh treatments enriched with RPS had considerably greater WHC% (P<0.0001). According to the findings, RPS_3 had the greatest WHC% (35.83±3.91 and 34.40±4.76%) at zero time and after four weeks of storage, followed by RPS_2 and RPS_1. Furthermore, RPS_3 exhibited the lowest syneresis both fresh or after 29 days of storage, 8.1±1.11 and 7.2±1.32 (g/100g labneh). While FBC had the greatest Syneresis compared to other treatments 13.4±2.30 and 11.0±1.53 respectively (g/100g labneh). This might be because starch particles bind more water from the surrounding protein matrix, generating swelling and restricting syneresis, and these gels had a smooth texture. The inclusion of RPS improved the increase in water holding capacity and eliminated the syneresis of low-fat Labneh cheese, which is consistent with those reported by Abbas, et al.; Ahmad, et al.; Shams El Din, et al. [1]; [3]; [33]. Furthermore, they indicated that enzymatically hydrolyzed potato powder had high rheological properties in yoghurt particularly, texture profile analysis which is regarded as one of the most critical metrics in determining Labneh quality.



Streptococcus thermophiles

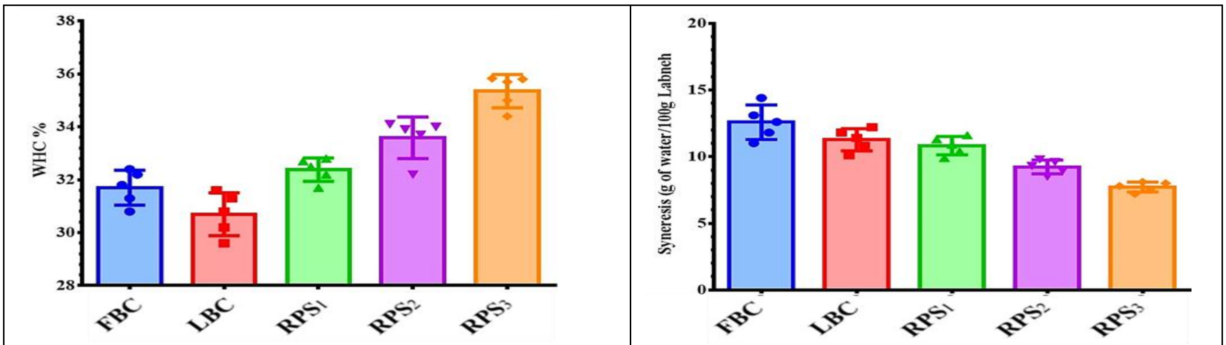
Lactobacillus delbrucii subsp *bulgaricus*

Total bacterial count

Mold, yeast

FBC, Full-fat Labneh cheese control ; LBC,Low-Fat Labneh cheese control; RPS_1, Low-Fat Labneh (0.5% resistant potato starch); RPS_2, Low-Fat Labneh (1.0% resistant potato starch); RPS_3, Low-fat Labneh (1.5% resistant potato starch).

Figure 1. Microbiological assessment of low-fat labneh fortified with different levels of RPS durig the storage.

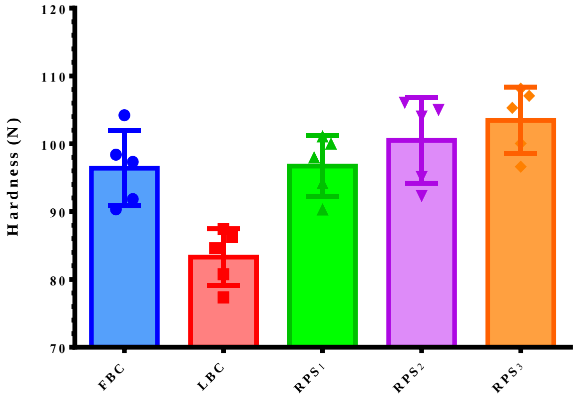


WHC %	Syneresis (g of water/100g Labneh)

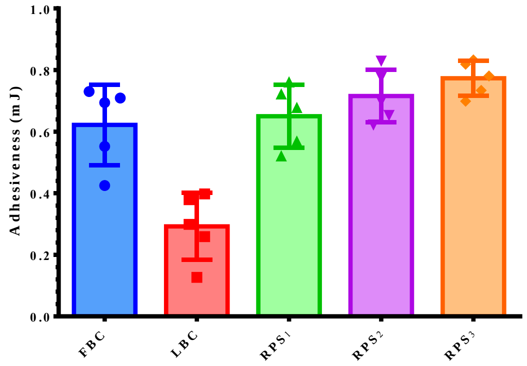
FBC, Full-fat Labneh cheese control ; LBC,Low-Fat Labneh cheese control; RPS_1, Low-Fat Labneh (0.5% resistant potato starch); RPS_2, Low-Fat Labneh (1.0% resistant potato starch); RPS_3, Low-fat Labneh (1.5% resistant potato starch).

Figure 2. Water holding capacity (WHC) and syneresis susceptibility of low-fat Labneh cheese fortified with different levels of RPS during the storage

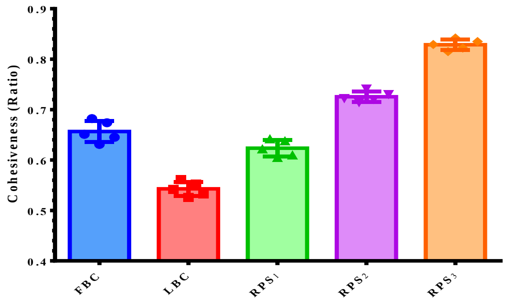
Texture profile analysis (TPA) of low-fat Labneh cheese



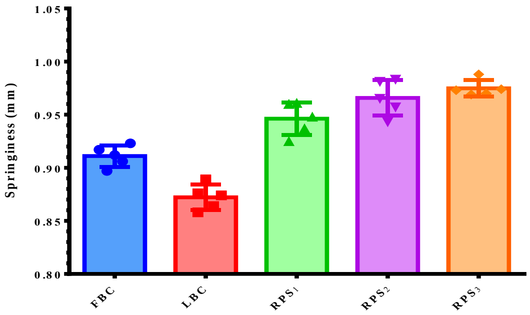
Hardness (N)



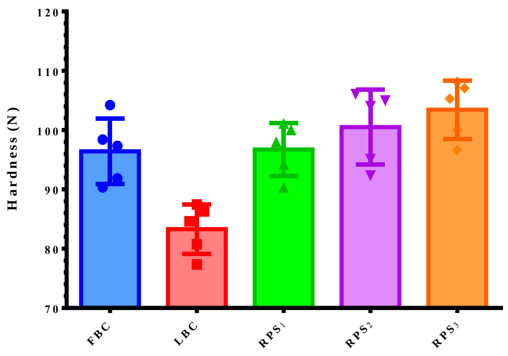
Adhesiveness (mJ)



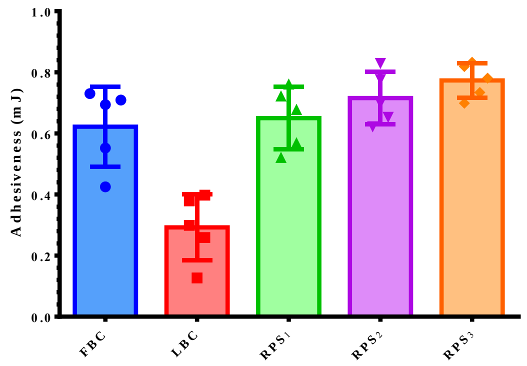
Cohesiveness (Ratio)



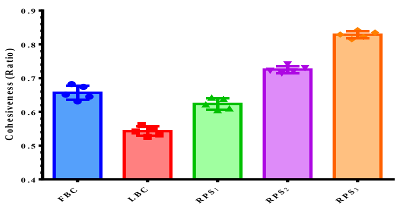
Springiness (mm)



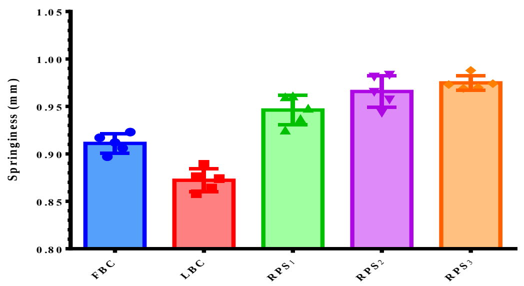
Hardness (N)



Adhesiveness (mJ)



Cohesiveness (Ratio)



Springiness (mm)

Figure 3. Texture profile analysis of Labneh fortified with fortified with different levels of RPS during the storage.FBC, Full-fat Labneh cheese control ; LBC,Low-Fat Labneh cheese control; RPS_1, Low-Fat Labneh (0.5% resistant potato starch); RPS_2, Low-Fat Labneh (1.0% resistant potato starch); RPS_3, Low-fat Labneh (1.5% resistant potato starch).

Figure 3 illustrates the TPA outcomes of the Labneh textural profile analysis (TPA). It showed TPA values varied significantly (P<0.0001) across all treatments. The inclusion of RPS in the production of Labneh has been attributed to its extreme hardness. RPS_3 treatment resulted in 108.14±3.91 and 96.64±4.76,whereas FBC resulted in 104.21±4.21 and 90.34±3.91. Texture profile analysis demonstrated the same pattern for cohesiveness, springiness, chewiness, adhesiveness, and gumminess at zero time and after 4 weeks of storage. Texture profile analysis (TPA) results agreed with Abbas, et al., Shams El Din, et al. [1], [33].

Microstructural of low-fat Labneh cheese (SEM)

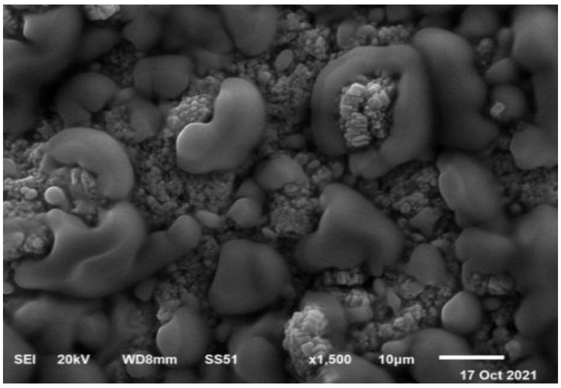
Scanning electron micrographs indicated that the morphology, size, and distribution of the fat droplets varied with the added RPS level. Microstructure analysis demonstrated that the internal structure of low-fat labneh formulated with RPS was dense and smoother than the surfaces of control samples (Fig. 4). The control of full-fat labneh and the control of low-fat labneh (FBL and LBL) showed coarse, granular, and rough outer surfaces. By comparison, the low-fat milk with MPS had denser, smoother structures. These structural features may be associated with the textural attributes of the product. Hence, it can be hypothesized that the control sample induced a more interspersed and heterogeneous structure due to protein or fat non-integration. Treated low-fat labneh with RPS had a more systematically and smoothly distributed casein with a bit of a coarse structure as well as less porosity in the casein network. These structural features may be associated with the textural attributes of the product. Hence, it can be hypothesized that the control sample induced more interspersed and heterogeneous structure due to protein or fat non-integration. The difference in the distribution of casein in the treatments might be attributed to hydrocolloids and emulsion stability catalyzed cross-link formation between milk proteins, as reported by Li, et al.; Lorenzen, et al.; Shams El Din, et al. [17], [19], and [33] , less defined. Also, These differences were probably due to the interactions between casein micelles and stabilizers through mainly hydrophobic interactions, leading to the formation of casein-stabilizer complexes [29]. When low levels of RPS were added, it was confined to a dispersed phase and behaved as a filler, resulting in the protein matrix becoming more compact and an increase in the gel strength of the low-fat labneh. Adding RPS formed a stranded network from the protein phase and fat. This probably explains the harder texture observed in the low-fat labneh made with RPS (Fig. 1). These results are in agreement with EL-Dardiry, Salah and Alaa; Thérèse, et al. [11], [31], and [38].

Sensory evaluation of low-fat Labneh enriched with RPS

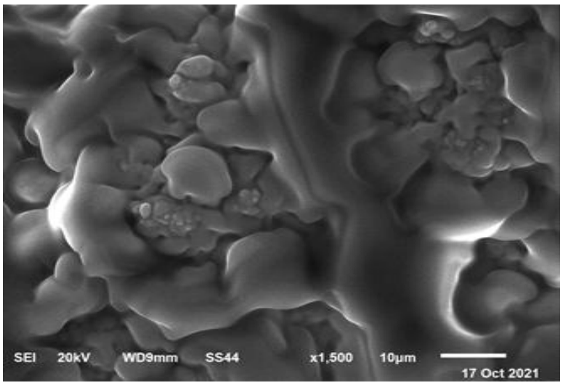
Figure 5. depicts the sensory evaluation of low-fat Labneh enriched with RPS after 29 days of cold storage at 5±1°C. The results revealed that there were substantial variations in the appearance, body, texture, and flavor of Labneh samples (P<0.0001). The results show that the Labneh enriched with RPS, particularly RPS_2 and RPS_3, is similar to the control FBC in appearance, smoothness, and texture during the zero time and the first week of storage. After that, the sensory evaluation scores go through the RPS-enriched treatments over the storage time.

4.CONCLUSION

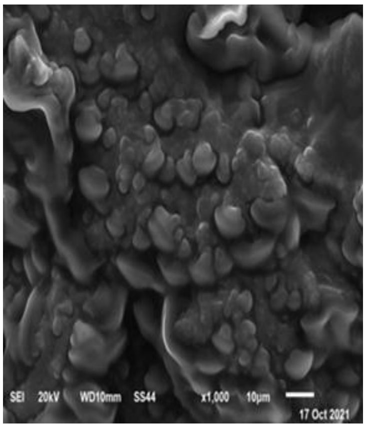
Resistant potato starch is used in dairy products as a fat substitute (Fat mimetics) and prebiotic, which promotes probiotics and human health. After four weeks of storage, the organoleptic, physicochemical, microbiological, and rheological properties of low-fat labneh cheese were evaluated. The results showed that RPS had a significant effect on the composition and rheological properties of low-fat labneh cheese during storage. It also has a significant effect on the number of probiotic bacteria and sensory evaluation. As a result, we recommended the use of RPS as a functional ingredient in low-fat functional labneh cheese to replace the fat in functional dairy products.

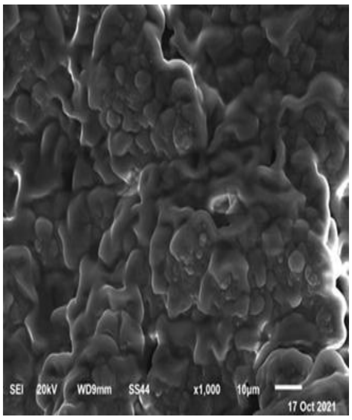


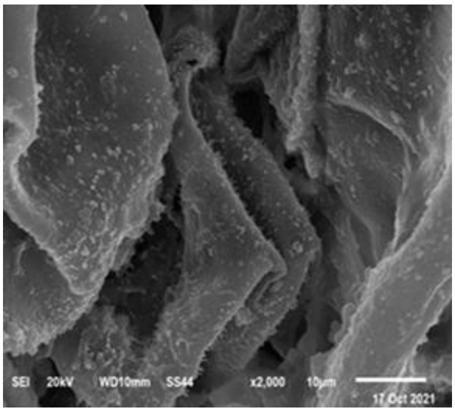
FBC



LBC



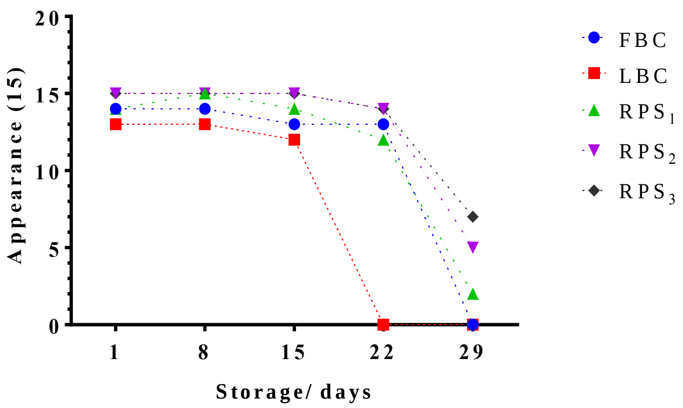




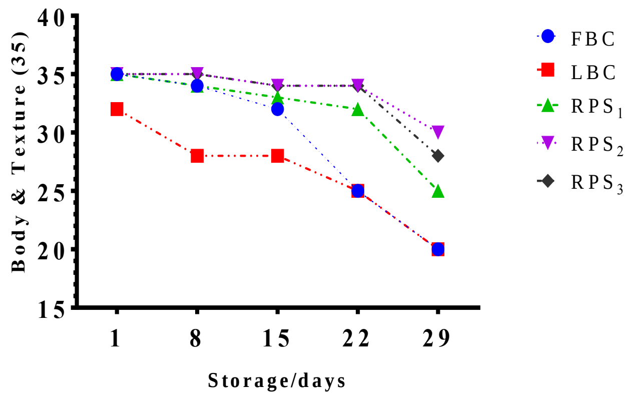
RPS_1 RPS_2 RPS_3

Flg.4. Scanning electron microscopy of low-fat labneh manufacture with different levels of RPS FBC, Full-fat Labneh cheese control ; LBC,Low-Fat Labneh cheese control; RPS_1, Low-Fat Labneh (0.5% resistant potato starch); RPS_2, Low-Fat Labneh (1.0% resistant potato starch); RPS_3, Low-fat Labneh (1.5% resistant potato starch).

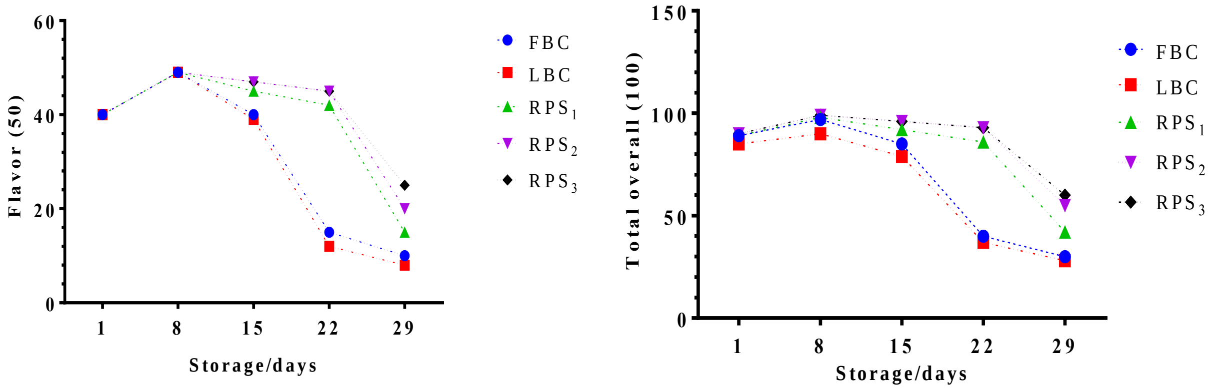
Figure 4. Microstructure of low-fat Labneh cheese fortified with different levels of RPS



Appearance (15)



Body & Texture (35)



Flavor (50) Total overall (100)

FBC, Full-fat Labneh cheese control ; LBC,Low-Fat Labneh cheese control; RPS_1, Low-Fat Labneh (0.5% resistant potato starch); RPS_2, Low-Fat Labneh (1.0% resistant potato starch); RPS_3, Low-fat Labneh (1.5% resistant potato starch).

Figure 5. Sensory evaluation of low-fat Labneh cheese fortified with different levels of RPS during the storage

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