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Research Article

Improving the Functional and Sensory Properties of Cookies by Ultrasonic Treatment of Whey Proteins

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The profiles of food products are one interesting link that adds a new functional component. Cookies became one of the remarkable foods as a result of their simple preparation, a protracted period, and a sensible acceptance by the population. The effects of sonication on physical and sensory characteristics of cookies to be enhanced were studied. The results showed that cookies prepared with 5 and 10% replacement of sonicated whey protein had significant differences in sensory evaluation especially crumb, but there were no significant differences in the physical characteristics, so we can conclude that sonication will improve sensory properties of cookies. Also, we can conclude that biscuit samples supplemented with 5 or 10% WPC were nutrient-rich. The results of the sensory evaluation showed that the cookie samples supplemented with 5% WPC performed better in most of the characteristics but decreased with an increase in the WPC level. The texture properties of the cookie samples indicated that the control cookies with WPC-supplemented cookies showed no significant differences in most studied properties. It can be concluded that the addition of sonicated whey protein enhanced the physiochemical and sensory properties of cookies.

1. Introduction

Recently, the demand for consuming nutritionally rich products has been increasing among consumers, and these products are ready to eat, have a long shelf life, and are categorized as high and good quality protein contents [1]. Cookies are one of the interesting food products that add a new functional ingredient, because they are easy to prepare, have a long shelf life, and have good acceptance by the population [2], and they are considered as the largest category of snacks around the world [3]. The manufacturing process of cookies was investigated by the authors in [3], and they said that the process was easy and took only 30 min. First, fat and sugar were being creamed to a smooth consistency, then, eggs and milk were added and mixed, and after that, dry ingredients such as flour, baking powder, and salt were mixed together, followed by adding cream, vanilla extract, and nutmeg and then mixing to form dough. The dough was then placed in greased pans, and eggs were washed; finally, the cookies were baked at 150°C/20 min. In addition, eggs are used instead of water for proper dough formation [1] and milk is added due to its content of protein which contributes to structural properties of products such as emulsion, foaming, and gel properties [4]. Whey is a collective term referring to the serum of watery portion that separates from curd during conventional cheese making [5].

Main proteins present in milk are whey and casein, and also, milk is rich in calcium, phosphorus, essential amino acids, and water-soluble vitamins, which makes whey a highly nutritious product [6]. Whey protein concentrates (WPCs) have been found to be used in biscuits, cookies, cakes, sponges, icings, and glazes to improve texture, flavor, and appearance [7]. Also, whey can be used to produce refreshing beverages [8]. Guimaraes [9] showed that beverages based on whey with at least 51% (m./m.) of content are typically made from ingredients that consist of dairy compounds (liquid or powdered milk and whey). Furthermore, whey is characterized by excellent nutritional and functional properties and low cost of production [10, 11]; however, its nutritional and functional properties can be enhanced by incorporating other ingredients such as fruit pulp and prebiotics [9]. Also, Lagrange [12] showed that in the last decades, the demand for high protein dairy powders increased like a whey protein isolate. Guralnick [13] explained that these powders provide a high-quality protein source and have a wide range of functional properties desired during processing and in finished product applications.

Tirloni [14] explained that whey proteins are also used in sports beverages, due to special functionality and high nutritional values. Wheat flour is considered to be the basic ingredient for bakery products such as chapatis, rotis, paratha, bread, buns, cookies, cakes, patties, and pancakes [15]. The chemical composition of whole-wheat flour is as follows: moisture (9.38–10.43%), ash (1.32–1.85%), crude protein (10.13–14.74%), crude fat (1.96–2.52%), crude fiber (2.31–2.99%), nitrogen-free extract (78.71–85.37%), wet gluten (23.53–38.71%), and dry gluten (7.51–13.52%) among different wheat [16]. On the other hand, ultrasound (US) is defined as waves of a mechanical nature that require an elastic medium to propagate, US waves propagate at frequencies greater than 20 kHz (upper limit of audibility for the human ear), and US has been applied to food technologies due to its mechanical and/or chemical effects on improving the processes of homogenization, mixing, filtration, crystallization, dehydration, and others [17]. Frequency, processing time, and power of ultrasound are factors which have significant effects on food [18]. Ultrasound treatment is one of the nonthermal technologies that are studied regarding microbial inactivation and microstructural changes, so this technology is important in dairy products, which represents one of the most important sectors of the food industry and has a wide range of products developed from various processes [19]. Ultrasound frequency range is divided into two types: low and high frequencies. Low frequencies use intensities below 1 W/cm2 and higher than 100 kHz. High frequencies use intensities higher than 1 W/m2 and between 20 and 500 kHz [20]. Results showed that high pressure and US vibrations significantly affect the physical and structural properties of proteins, When whey protein concentrate was treated with ultrasound, a reduction in molecular size was observed. This indicates that ultrasound increased the particle size and decreased the range for particle size distribution. This resulted in the formation of molecule aggregates [21].

2. Materials and Methods

Soft wheat flour, sugar, and shortening was procured from the local market of Jordan and kept at room temperature for further use. All chemicals used were of analytical grade.

2.1. Sample Preparation of Cookies. Three levels of whey protein concentrate (WPC) were used to prepare cookies along with wheat flour. Dough was prepared for 30 min and sheeted manually to a thickness of 5 mm by means of a rolling pin. After that, the cookies were cut by using a 50 mm diameter cookie cutter. Then, they were baked at 220°C for 10 min in an oven and cooled at room temperature for one hour and packed in sealed polythene bags for further analysis.

2.2. Proximate Analysis of Cookies. The approximate composition of samples including moisture content, ash content, crude protein, crude fat, and crude fiber based on the dry weight were measured according to the American Association of Cereal Chemists (2000).

2.3. Spread Factor. The AACC Method 10-50D (1983) was used to evaluate the cookie width, thickness, and spread factor. The cookie width (W) was measured by placing six cookies edge to edge to get the average width in mm. The cookie thickness (T) was measured by stacking six cookies on top of each other and restacking in different order and remeasuring them to get the average in mm. The spread factor (SF) was determined from width and thickness as shown in the following equation:

$$SF = \left[\left(\frac{W}{T}\right) \times C.F \times 10\right]. \tag{1}$$

C.F is the correction factor for adjusting W/T (as is) to constant atmospheric pressure. For this work, C.F was taken to be 1.0.

2.4. Sensory Properties of Cookies

2.4.1. Consumer Test. The consumer sample population was selected from the database of consumers in Jordan University of Science and Technology, who were 18–60 years of age and of various socioeconomic backgrounds. Consumers responded to an e-mail survey questionnaire including demographics as well as the consumption frequency of biscuits. Only those who consumed biscuits at least once per week were selected to participate in the assessment, with a target of 60 participants (36 males and 24 females).

Consumer testing was conducted at the Jordan University of Science and Technology Sensory Analysis Laboratories. Respondents were provided with ID cards in the order in which they arrive at the test site and directed to

Table 1: Definition, evaluation procedure, scale, and references used for the attribute measurement.

Descriptor	Definition	Scales and references	
Appearance whey presence	Visual observation of whey	Absence(0)	Amount as a teaspoon (10)
Mouth texture friability	Ability to generate cheese fragment from the beginning of chewing	Skimmed plain yoghurt Larsa(0)	Curd brand Asturiana (10)
Solubility	Ability of the sample to melt with saliva	Curd Asturiana (5)	
Moistness	Perception of water absorbed or released by that product during early mastication	Banana (0)	Skimmed plain yoghurt Larsa (10)
Graininess	Perception of coarse particles in the mouth	Whey cheese Arquega (5)	
Floury	Perception of floury texture in the mouth	Ripe golden apple (0)	Canned beans without skin (10)
Creaminess	Perception of thickness and smoothness pressing the sample between the tongue and palate	Skimmed plain yoghurt (0)	Spreadable cheese Philadelphia (10)
Taste and aroma			
Acid taste	Basic taste similar to that of diluted aqueous solution of citric acid	0.13 g/L (5)	
Salty taste	Basic taste similar to that of diluted aqueous solution of sodium chloride	0.70 g/L (5)	
Bitter taste	Basic taste similar to that of diluted aqueous solution of caffeine	0.54 g/L (5)	
Fresh cheese flavor	Intensity of the olfactory- gustatory sensation perceived during mastication associated with typical aroma of fresh cheese	Commercial cheese Burgos type (5)	
Milk flavor	Intensity of the olfactory-gustatory sensation perceived during mastication associated with raw milk at room temperature	Absence (0)	Full fat milk (10)
Strange flavor	No typical aromas related to fresh cheese	Absence (0)	Intense (10)
After taste	Intensity of the olfactory-gustatory sensation perceived after mastication and swallowing the sample	Absence (0)	Intense (10)
Persistency	Duration of the olfactory-gustatory sensation perceived after the bolus leaves of the mouth	≤10 s	≥60 s (10)

individual test booths with written instructions and balloting. A blind basis method of analysis was used, where samples were coded with randomly selected 3 digit numbers and balanced ordered testing.

Each consumer was provided with a tray containing 6 pieces of biscuit treatments (for each of sample) in 50 mL plastic sample containers. To eliminate carry over factors, consumers were also provided with unsalted crackers and room temperature water for mouth cleansing between samples. The consumers were asked to record their acceptance and intensity scores for overall impression, overall flavor, overall texture, and overall color (9 point scale with 9 = "like extremely" and 1 = "dislike extremely"); crust and crumb (just about the right scale with 1 = much too rough walls and no pores, 2 = too rough walls and no pores, 3 = just about right, 4 = too soft walls and pores, and 5 = much too soft walls and pores); hardness (just about the right scale with 1 = "much too soft" and 5 = "much too hard"); adhesiveness (just about the right scale with 1 = much too nonadhesive, 2 = too non-adhesive, 3 = just about right, 4 = too adhesive, and 5 = much too adhesive).

2.4.2. Quantitative Descriptive Analysis. The quantitative descriptive analysis was carried out with a panel of trained tasters, which included 15 tasters with previous experience in the sensory evaluation of cookies [22]. The descriptor set was generated according to the standards of sensory analysis. Descriptors and references to an anchor scale are listed in Table 1. The procedures for selection and training of the judges were in accordance with standard international norms [22]. The trained panel generated the cookie set sensory descriptors, scales, and references to evaluate the sensory profile according to the standard norms [22].

2.5. Statistical Analysis. Data were analyzed using the general linear model (GLM) procedure with the SAS Version 8.2 software package (SAS 2002 Institute Inc., Cary, NC, USA). Means were separated by LSD analysis at a least significant difference of 0.05 p value.

3. Results and Discussion

3.1. Effect of WPC on Composition of Cookies. As shown in Table 2 (chemical composition before processing), the moisture content of cookies decreased from 12.50 to 10.55%. Control registered the highest moisture content (12.50%), while the lowest moisture content of 10.55% was found for WPCSH (10%). Our results are in good agreement with the findings of the authors in [23] regarding ash, protein, and fat contents where the proximate composition of samples differed slightly from that of the control sample. Gallagher [24] expressed that an increase in moisture content with the increasing WPC supplementation level may be due to more bound water in the system. Our result is not in good agreement with those of the authors in [25] who expressed that biscuits with WPC are higher in moisture content than those with the control sample. Protein content in cookies increased from 12.71 to 18.57%. The highest value for

Table 2: Chemical composition values before processing.

Sample	Moisture (%)			Ash (%)			Protein (%)			Fat (%)		
Flour (control)	12.50	±	0.90	0.48	±	0.04	12.71	±	1.12	0.91	±	0.08
WPC (5%)	11.80	±	0.76	0.58	±	0.20	15.66	±	1.39	0.98	±	0.09
WPCSL (5%)	11.73	±	0.72	0.61	±	0.17	15.82	±	1.07	0.97	±	0.08
WPCSH (5%)	11.56	±	0.67	0.63	±	0.12	15.71	±	1.11	0.98	±	0.08
WPC (10%)	10.82	±	0.67	0.72	±	0.13	18.48	±	1.14	1.08	±	0.07
WPCSL (10%)	10.62	±	0.71	0.71	±	0.12	18.51	±	1.13	1.10	±	0.07
WPCSH (10%)	10.55	±	0.32	0.69	±	0.24	18.57	±	1.17	1.09	±	0.05

(i) WPC (5%) whey protein concentrate + 95% flour, (ii) WPCSL (5%) with sonication low, (iii) WPCSL (5%) with sonication high, (iv) WPCSL (10%) with sonication low and 10% WPC, and (v) * means ± SD in the same column with the same letters are not significantly different ($P \leq 0.05$).

Table 3: Chemical composition after processing.

Treatment	Moisture (%)				Ash (%)				Protein (%)				Fat (%)			
Flour (control)	4.12	d	±	0.22	1.43	b	±	0.10	15.83	c	±	1.21	1.62	c	±	0.90
WPC (5%)	4.32	c	±	0.23	1.47	ab	±	0.08	18.79	b	±	1.27	1.82	b	±	0.79
WPCSL (5%)	4.49	bc	±	0.22	1.46	ab	±	0.07	18.88	b	±	1.32	1.88	ab	±	1.00
WPCSH (5%)	1.68	B	±	0.24	1.49	ab	±	0.06	18.96	b	±	1.24	1.89	ab	±	1.09
WPC (10%)	4.76	ab	±	0.23	1.52	a	±	0.08	21.74	a	±	1.25	1.96	a	±	0.86
WPCSL (10%)	4.87	a	±	0.27	1.57	a	±	0.08	21.78	a	±	1.29	1.97	a	±	1.04
WPCSH (10%)	4.93	a	±	0.17	1.59	a	±	0.07	21.89	a	±	1.34	1.98	a	±	1.15

(i) WPC (5%) whey protein concentrate + 95% flour, (ii) WPCSL (5%) with sonication low, (iii) WPCSL (5%) with sonication high, (iv) WPCSL (10%) with sonication low and 10% WPC, and (v) *means ± SD in the same column with the same letters are not significantly different ($P \leq 0.05$).

Table 4: Physical characteristics of different levels of replacement.

Treatment	Weight (gm)*			Width (cm)*			Thickness (cm)*			Spread factor*			
Flour (control)	61.82	±	3.11	5.06	±	0.23	0.84	±	0.04	56.11	±	3.51	c
WPC (5%)	62.17	±	3.14	5.31	±	0.22	0.88	±	0.04	56.36	±	3.51	bc
WPCSL (5%)	62.28	±	3.17	5.12	±	0.25	0.87	±	0.03	56.91	±	3.50	bc
WPCSH (5%)	61.23	±	3.22	5.21	±	0.31	0.87	±	0.07	57.26	±	3.15	bc
WPC (10%)	61.21	±	3.25	5.42	±	0.25	0.89	±	0.05	57.81	±	4.02	ab
WPCSL (10%)	60.36	±	3.36	5.22	±	0.31	0.87	±	0.05	58.24	±	4.95	ab
WPCSH (10%)	61.68	±	3.23	5.28	±	0.34	0.90	±	0.07	59.45	±	2.97	a**

(i) WPC (5%) whey protein concentrate + 95% flour, (ii) WPCSL (5%) with sonication low, (iii) WPCSL (5%) with sonication high, (iv) WPCSL (10%) with sonication low and 10% WPC, and (v) *means ± SD in the same column with the same letters are not significantly different ($P \leq 0.05$).

protein content (18.57%) was in WPCSH10%, while the lowest value of 12.71% was in the control sample. The results showed that the protein content of all samples differed greatly. Our results agreed with those of the authors in [7] for WPC-enriched biscuits. Also, fat content of cookies slightly increased from 0.91 to 1.09%. The highest value of fat (1.09%) was observed in WPCSH10%, while the lowest value (0.91%) was observed in control samples. Singh and Mohamed [26] results showed the same variations in fat content of soy-fortified cookies. Finally, ash content of cookies increased from 0.48 to 0.72%. The highest value of ash content (0.72%) was reported in WPC 10%, while the lowest value for ash content (0.48%) was observed in control samples. This result agreed with that of the authors in [25], and they found that ash content in biscuits enriched with the WPC and casein increase.

On the other hand, Table 3 (chemical composition after processing) shows the moisture content of cookies increased from 4.12 to 4.93%, where the highest moisture content (4.93%) was observed in WPCSH10%, while the lowest moisture content of 4.12% was found in control samples. Also, protein content in cookies increased from 15.83 to 21.89%, and this could be linked with increased protein denaturation due to a cavitation effect between myofibrils and thus an increase in protein content [27]. However, the highest value of protein content (21.89%) was observed in WPCSH10%, while the lowest value of (15.83%) was reported in control samples. Moreover, fat content of cookies increased from 1.62 to 1.98%. The highest value of fat (1.98%) was observed in WPCSH10%, while the lowest value (1.62%) was observed in the control sample. The authors in [28] reported that sonication leads to an increase in fat concentration, which was demonstrated by the larger surface area of fat globules after ultrasonication treatment, which resulted in an increase in light scattering. Ash content of cookies increased from 1.43 to 1.59%. The highest value of ash content (1.59%) was reported in WPCSH 10%, while the lowest value of ash content (1.43%) was observed in control samples.

3.2. Effect of WPC on Dimensional Characteristics of Cookies.

Table 4 shows physical characteristics of different levels of replacement, which shows that the thickness of

Table 5: Sensory consumer analysis.

Treatment	Overall		Flavor		Texture		Color		Crust (JAR)		Crumb (JAR)		Hardness (JAR)		Color (JAR)		Adhesiveness (JAR)	
Flour (control)	6.95	c	6.15	b	6.54	c	6.11	b	2.11	a	1.81	c	3.47	a	2.44	a	3.21	d
WPC (5%)	7.11	bc	6.18	b	6.62	bc	6.14	ab	2.13	a	1.88	bc	3.35	a	2.41	a	3.38	c
WPCSL (5%)	7.17	bc	6.20	b	6.68	ab	6.17	ab	2.17	a	1.94	b	3.31	ab	2.38	a	3.41	bc
PCSH (5%)	7.26	b	6.21	b	6.69	ab	6.15	ab	2.18	a	1.99	b	3.27	b	2.37	a	3.48	b
WPC (10%)	7.32	ab	6.37	a	6.72	ab	6.25	a	2.13	a	2.06	ab	3.22	bc	2.31	ab	3.53	b
WPCSL (10%)	7.38	a	6.35	a	6.81	a	6.27	a	2.14	a	2.13	a	3.21	bc	2.31	ab	3.64	a
WPCSH (10%)	7.45	a	6.36	a	6.85	a	6.31	a	2.15	a	2.18	a	3.13	c	2.25	b	3.68	a

(i) WPC (5%) whey protein concentrate + 95% flour, (ii) WPCSL (5%) with sonication low, (iii)WPCSL (5%) with sonication high, (iv) WPCSL (10%) with sonication low and 10% WPC, and (v) *means in the same column with the same letters are not significantly different ($P \leq 0.05$).

cookies increases with an increase in the WPC supplementation level in wheat flour. However, the findings of the authors in [25] agreed with our results. Significant difference in thickness was observed for samples WPC, WPCSL, and WPCSH, and the obtained results are similar to those found by the authors in [29]who stated that the thickness of WPC-fortified biscuits was greater than that of control biscuits. As biscuits shrunk (diameter decreasing), the decrease in diameter was compensated by the expansion of the thickness, which was the cause of the increased thickness. On the other hand, each decrease in weight of cookies showed an increase in the level of WPC supplementation, and there were significant differences in weight in WPC, WPCSL, and WPCSH, which can be related to the addition of excess water in the formulation of WPC-fortified dough than control biscuit dough [29]. Mishra and Chandra [30] reported that there was a decrease in the diameter in rice bran and soy-fortified biscuits. There was an increase in the spread factor in WPC-supplemented cookies, and a significant difference in weight was observed for samples WPC, WPCSL, and WPCSH and width of cookies with an increase in the level of WPC supplementation. A significant difference in width was also observed for samples WPC, WPCSL, and WPCSH. There is a significant difference in the spread ratio for all cookies, and our results are in compliance with those of the authors in [31] who reported that there was a significant increase observed ($P \leq 0.05$) as the levels of whey protein concentrates increased. Maybe the increase in the rate of prevalence in the definition files is complementary because of the link for WPC significant reduction in the thickness of the complementary profile link for WPC. Similar results were observed in the rate of prevalence by the authors in [32] in the definition of complementary file link powder islands. Also, the author in [33] noticed an increase in the value of the factor in the spread of complementary millet flour biscuits.

3.3. Effect of WPC Sensory Perception of Cookies. The study of consumers' perception can be of major worth to industrial community since it helps in identifying the negative and positive factors that guide the consumer behavior and purchase habits [34]. The results for the sensory evaluation of cookies are given in Table 5 (sensory consumer analysis), and the overall mean score increased from 6.95 to 7.45. The highest score (7.45) was observed in WPCSH 10%, while the lowest mean score (6.95) was observed in control, and flavor increased from 6.15 to 6.37. The highest score (6.37) was observed in WPC 10%, while the lowest mean score (6.15) was observed in control. The mean score of texture increased from 6.54 to 6.85 with the increasing level of WPC supplementation. The highest score of 6.85 was noticed in WPCSH10%, while the lowest mean score (6.54) was noticed in control. The mean score of color increased from 6.11 to 6.31. The highest score (6.31) was observed in WPCSH 10%, while the lowest mean score (6.11) was observed in control. The crust (JAR) mean score increased from 2.11 to 2.18. The highest score (2.18) was observed in WPCSH 5%, while the lowest mean score (2.11) was observed in control. The crumb (JAR) mean score increased from 1.81 to 2.18. The highest score (2.18) was observed in WPCSH 10%, while the lowest mean score (1.81) was observed in control. The mean score of hardness decreased from 3.47 to 3.12 with the increasing level of WPC supplementation. The lowest score of 3.12 was noticed in WPCSH10%, while the highest mean score (3.47) was noticed in control. The color (JAR) mean score decreased from 2.44 to 2.25. The lowest score (2.25) was observed in WPCSH 10%, while the highest mean score (2.44) was observed in control, and the adhesiveness mean score increased from 3.21 to 3.68. The highest score (3.68) was observed in WPCSH 10%, while the lowest mean score (3.21) was observed in control. The findings obtained from the current work agree well with those of Singh et al. [35]who found the overall acceptability score of sensory evaluation in soy flour-fortified biscuits. Ahmed and Ashraf [31] found that the significant difference in sensory evaluation between samples (5% and 10%) and results regarding color could be related to the Maillard reaction between reducing sugars and proteins.

4. Conclusion

From the present study, it can be concluded that 5% WPC-supplemented cookie samples are nutritionally rich. Sensory evaluation results revealed that 5% WPC-supplemented cookie samples scored highest in most of the attributes. Diameter, thickness, and weight of the cookie samples decreased with an increase in the WPC level. The textural characteristics of cookie samples indicated that control and WPC-supplemented cookies did not show significant differences. This study concluded that the supplementation level of 5% WPC results in acceptable sensory, textural, and physiochemical characteristics.

Data Availability

The data are available upon request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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