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Effect of Adding Whey on the Chemical Properties and Sensory Qualities of a Loaf of Bread

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تأثير إضافة شرش اللبن على الخواص الكيميائية والصفات الحسية لرغيف الخبز

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Abstract

This study investigated the effect of using whey as a substitute for water during breadmaking on the chemical composition and sensory properties of the resulting bread. Five treatments of baladi bread were prepared by replacing the water added during kneading with whey at levels of 0%, 25%, 50%, 75%, and 100%; the 0% treatment served as the control. The chemical composition and sensory properties of the final product were evaluated. Significant differences were observed in the chemical composition. Protein content increased from 10.71% in the control to 11.40%, 11.95%, 12.61%, and 13.49% with increasing whey substitution, respectively. Fat content was 1.43%, 1.33%, 1.49%, 1.78%, and 2.02%, respectively, while moisture content was 36.15%, 36.50%, 36.65%, 36.71%, and 36.77%, respectively. Ash content was 1.24%, 1.31%, 1.44%, 1.64%, and 1.88%, respectively. No significant effect was observed on dietary fiber content. Total carbohydrate content was 47.45%, 46.37%, 45.36%, 44.07%, and 42.55%, respectively. Sensory evaluation on a nine-point hedonic scale showed significant differences among treatments in color, texture, and overall acceptability, whereas no significant differences were detected in taste or aroma. Thus, whey may be recommended as a substitute for water in breadmaking because it improves the nutritional value and selected sensory attributes of the final product.

Keywords: whey; bread; chemical properties; sensory qualities.

الملخص

هدفت هذه الدراسة إلى بحث تأثير استخدام شرش اللبن بديلًا للماء أثناء صناعة الخبز في التركيب الكيميائي والصفات الحسية للخبز الناتج. أُعدّت خمس معاملات من الخبز البلدي باستبدال ماء العجن بشرش اللبن بنسب 0% و25% و50% و75% و100%، واستُخدمت معاملة 0% بوصفها عينة شاهدة. قُيّمت الخواص الكيميائية والصفات الحسية للمنتج النهائي. أظهرت النتائج وجود فروق معنوية في التركيب الكيميائي؛ إذ ارتفعت نسبة البروتين من 10.71% في العينة الشاهدة إلى 11.40% و11.95% و12.61% و13.49% مع زيادة نسبة الاستبدال. وبلغت نسب الدهن 1.43% و1.33% و1.49% و1.78% و2.02%، في حين بلغت الرطوبة 36.15% و36.50% و36.65% و36.71% و36.77%، والرماد 1.24% و1.31% و1.44% و1.64% و1.88% على التوالي. ولم يظهر تأثير معنوي في محتوى الألياف الغذائية. أما الكربوهيدرات الكلية فانخفضت من 47.45% إلى 46.37% و45.36% و44.07% و42.55% على التوالي. وأظهر التقييم الحسي باستخدام مقياس القبول ذي النقاط التسع وجود فروق معنوية في اللون والقوام والقبول العام، في حين لم تظهر فروق معنوية في الطعم أو الرائحة. وبناءً على ذلك، يمكن استخدام شرش اللبن بديلًا للماء في صناعة الخبز لتحسين القيمة الغذائية وبعض الصفات الحسية للمنتج النهائي.

الكلمات المفتاحية: شرش اللبن؛ الخبز؛ الخواص الكيميائية؛ الصفات الحسية

Introduction

Whey is one of the major by-products of the dairy industry worldwide. However, a substantial proportion remains underutilized, resulting in considerable loss of potentially valuable nutrients and serious environmental pollution because of its high biological oxygen demand (BOD), reported to range from 30,000 to 50,000 mg/L. Whey is often discharged with wastewater, although it contains numerous organic compounds that can harm ecosystems. Accordingly, appropriate routes for whey utilization are needed both to prevent pollution and to avoid the loss of nutritionally valuable solids [9].

Whey is obtained mainly during cheese production through either traditional or modern processes. It is commonly classified as sweet whey, with a pH ranging from 6.02 to 6.58, and acid whey, with a pH ranging from 3.57 to 4.34. Most whey produced worldwide is sweet whey, defined as the liquid remaining after separation of the cheese curd formed by coagulation of milk proteins using acids or enzymes [11]. On a dry-weight basis, whey contains lactose (70–72% of total solids), proteins (8–10%), and minerals (12–15%). It is an excellent source of functional proteins, peptides, lipids, vitamins, and minerals. Whey proteins include β-lactoglobulin, α-lactalbumin, glycomacropeptide, lactoferrin, lactoperoxidase, and the enzyme lysozyme, several of which are associated with immune-related functions [11]. Evidence indicates that whey protein has high nutritional quality and a biological value exceeding that of several commonly used proteins, including egg protein, largely because of its high content of essential amino acids, particularly the branched-chain amino acids leucine, isoleucine, and valine [15].

Bread is among the most widely consumed foods worldwide and is an essential component of the daily diet. Its quality and sensory characteristics are important to consumers. Nevertheless, wheat flour is relatively limited in nutritional quality because it is deficient in certain essential amino acids, particularly lysine, threonine, and tryptophan [13]. Reference [10] reported that replacing the water used in baladi breadmaking with cheese whey produced a significant, gradual increase in the levels of solids, protein, ash, carbohydrates, and various minerals in the resulting bread, while dietary fiber was not significantly affected. Sensory acceptability also increased as the proportion of whey used to replace kneading water increased. In another study, dried whey protein concentrate was added to bread [4]. Sensory evaluation indicated that the concentrate did not adversely affect taste, texture, or general appearance; rather, it improved the texture and increased overall consumer acceptability. In addition, [12] reported that adding 10% whey substantially improved bread volume and softness compared with the control. Improvements in taste and aroma were also observed, leading the authors to conclude that adding 10% whey to bread dough can improve the chemical and sensory properties of the finished bread.

Although numerous studies have examined the effects of whey on selected food products, a clear gap remains in studies linking chemical changes with sensory evaluation, particularly in traditional products. Therefore, this study aimed to determine the effect of replacing water with different proportions of whey on selected chemical properties and sensory attributes of bread loaves and to identify substitution levels that may be recommended for bread production.

Material and Methods

2.1 Materials

Whey samples were collected from a cheese and dairy-products factory in the Al-Souq Al-Sabt area, south of Tripoli, Libya. The samples were stored in opaque containers at 4°C. The necessary analyses were then performed, and the whey was added to the bread dough as a replacement for water during kneading at substitution levels of 0%, 25%, 50%, 75%, and 100%.

2.2 Methods

Bread preparation, chemical analyses, and sensory evaluation were conducted in the laboratories of Omar Al-Mukhtar University, Al-Bayda, Libya. Protein, fat, moisture, ash, and carbohydrate contents were determined according to the methods of the American Association of Cereal Chemists (AACC, 2000). Sensory evaluation was conducted using a 9-point hedonic scale according to AACC Method 74-10.01 (AACC, 2000).

2.3 Statistical Analysis

The data were analyzed using a completely randomized design (CRD) with three replicates. Analysis of variance (ANOVA) was performed to assess differences among treatments at a significance level of $p \leq 0.05$. Mean separation was conducted using the least significant difference (LSD) test. Statistical analyses were performed using SPSS Statistics, version 20.0.

Results and Discussion

Chemical Composition of Whey

Table 1. Chemical composition of whey on a wet-weight basis.

Parameter	Protein (%)	Fat (%)	Ash (%)	pH
Value ± SE	1.00 ± 0.20	0.60 ± 0.10	0.50 ± 0.10	6.20 ± 0.10

Table 1 presents the chemical composition of whey on a wet-weight basis. Protein, fat, and ash contents were 1.0%, 0.6%, and 0.5%, respectively, and the pH was 6.2. These findings were generally consistent with those reported by [9], who recorded protein, fat, and ash contents of 0.94%, 0.80%, and 0.46%, respectively, with a pH of 5.20. The results also agreed closely with [7], who reported a protein content of 1%, an ash content of 0.5–0.7%, and a pH of 6.2–6.4.

Effect of Whey Substitution on the Chemical Properties of Bread

Table 2. Effect of replacing water with whey on the chemical properties of bread.

Whey (%)	Water (%)	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Fiber (%)	Carbohydrates (%)
0	100	10.71 e	1.43 c	36.15 d	1.24 e	3.00 a	47.45 a
25	75	11.40 d	1.33 c	36.50 c	1.31 d	3.06 a	46.37 b
50	50	11.95 c	1.49 bc	36.65 b	1.44 c	3.00 a	45.36 c
75	25	12.61 b	1.78 ab	36.71 ab	1.64 b	3.10 a	44.07 d
100	0	13.49 a	2.02 a	36.77 a	1.88 a	3.06 a	42.55 e
LSD	—	0.04	0.33	0.33	0.30	0.13	0.00

Values followed by the same letter within a column are not significantly different ($p \leq 0.05$).

3.2.1 Protein

As shown in Table 2, statistical analysis revealed significant differences at $p \leq 0.05$ according to the LSD test. A positive relationship was observed between the whey-substitution level and bread protein content. Protein content increased from 10.71% in the control to 11.40%, 11.95%, 12.61%, and 13.49% as whey substitution increased from 25% to 100%. This increase may be attributed to the high-quality proteins present in whey, including albumins and globulins. When whey is incorporated into bread ingredients, these proteins become part of the dough, thereby increasing the protein content of the final product. These findings agree with [10], who reported an increase in baladi-bread protein content from 7.32% to 7.39% and 8.22% when kneading water was replaced with whey at 50% and 100%, respectively. They are also consistent with [8], who found that bread protein content increased from 11.24% to 11.30%, 11.37%, 11.42%, and 11.49% at whey-substitution levels of 0%, 25%, 50%, 75%, and 100%, respectively. Similarly, [6] reported a direct relationship between whey substitution and bread protein content, which increased from 5.68% to 5.81%, 5.89%, 6.04%, and 6.18% across the same substitution levels.

3.2.2 Fat

The highest fat content was recorded in bread prepared with 100% whey, whereas the lowest was found in the control prepared with 100% water. Fat content was 2.02% at 100% whey substitution and 1.78%, 1.49%, and 1.33% at 75%, 50%, and 25% substitution, respectively. This pattern may be explained by the presence of residual lipids in whey, which are transferred to the dough and increase the fat content of the bread. The findings agree with [6], who reported an increase in bread fat content from 1.33% to 1.37%, 1.41%, 1.45%, and 1.48% as whey substitution increased from 0% to 100%, and are also consistent with [10].

3.2.3 Moisture

Significant differences in moisture content were observed between the control and whey-substituted samples. Moisture increased progressively with whey substitution, from 36.15%, 36.50%, 36.65%, and 36.71% to 36.77% at substitution levels of 0%, 25%, 50%, 75%, and 100%, respectively. The increase may be related to the water-holding capacity of whey proteins, which can retain moisture because of their protein structure. This property may increase moisture retention in bread and help it remain soft for a longer period. These findings are consistent with [5], [8], and [10].

3.2.4 Ash

Significant differences were observed between the control and the whey-substituted bread samples. Ash content increased from 1.24% to 1.31%, 1.44%, 1.64%, and 1.88% as whey substitution increased from 0% to 25%, 50%, 75%, and 100%, respectively. This may be attributed to the minerals present in whey, including calcium, phosphorus, and potassium, which are transferred to the bread and increase its ash content. These results agree with [6], [8], and [10]. In contrast, [5] found that replacing 100% of the liquid with whey in biscuits decreased ash content.

3.2.5 Dietary Fiber

Statistical analysis showed no significant differences in bread fiber content at $p \leq 0.05$ according to the LSD test. Thus, whey addition did not affect the fiber content of the bread, which may be explained by the negligible fiber content of whey. This result agrees with [10].

3.2.6 Carbohydrates

Significant differences were observed in total carbohydrate content at $p \leq 0.05$. The effect of whey substitution was inverse: as the proportion of whey increased, carbohydrate content decreased. Carbohydrate content was 47.45% in the control and declined to 42.55% at 100% whey substitution. This decrease may be attributed to the concurrent increases in protein, fat, ash, and moisture contents. The result agrees with [8] but differs from the findings of [10].

Effect of Whey Substitution on the Sensory Properties of Bread

Table 3. Effect of whey-substitution levels on the sensory properties of bread.

Whey (%)	Water (%)	Color	Aroma	Texture	Taste	Overall acceptability
0	100	5.05 c	7.00 a	6.62 b	6.63 a	6.25 b
25	75	6.25 b	7.00 a	6.75 b	6.75 a	6.50 ab
50	50	6.25 b	7.25 a	7.13 ab	7.00 a	6.75 ab
75	25	7.25 a	7.50 a	7.25 a	7.13 a	6.75 ab
100	0	7.87 a	7.75 a	7.75 a	7.38 a	7.13 a
LSD	—	0.89	0.78	0.87	0.71	0.89

Values followed by the same letter within a column are not significantly different ($p \leq 0.05$).

Table 3 shows that replacing water with whey at 25%, 50%, 75%, and 100% affected bread color. Statistical analysis revealed significant differences at $p \leq 0.05$ according to the LSD test. Color scores increased with whey substitution, from 5.05 in the control to 7.87 at 100% whey. This may be due to the high lactose content of whey, which promotes Maillard reactions and crust browning, producing a desirable brown color [5]. The addition of dairy proteins may also promote Maillard reactions that influence flavor, stability, and color. Maillard browning is a desirable non-enzymatic reaction in food processing. It involves a series of reactions beginning with the reaction of amino groups in amino acids, peptides, or proteins with the glycosidic aldehyde groups of reducing sugars and ending with the formation of brown nitrogen-containing polymers known as melanoidins.

No significant differences were detected in aroma at $p \leq 0.05$. Similarly, taste did not differ significantly among treatments, although the highest taste score was recorded at 100% whey substitution (7.38). These findings agree with [2], who studied the use of whey powder as a substitute for cow's milk in breadmaking and reported that 71.5% of tasters found bread containing 100% whey highly acceptable. The resulting bread had acceptable characteristics and an attractive appearance, including a regular shape and a smooth crust.

Texture scores showed a positive relationship with whey substitution, with values of 6.62, 6.75, 7.13, and 7.75 at 25%, 50%, 75%, and 100% substitution, respectively. Statistical analysis indicated significant differences mainly between the lower and higher substitution levels.

According to Table 3, overall acceptability was not significantly affected by whey addition except at 100% substitution, where the score reached 7.13 compared with 6.25 in the control. The improvement may be related to whey proteins and lactose, as well as the emulsifying properties of whey, which can improve crumb structure and enhance flavor in bread and other baked products [16]. Reference [3] likewise reported the highest sensory scores when whey and buttermilk were added compared with the control; whey-containing samples received higher consumer acceptance for taste and texture. Reference [14] attributed the improvement in bread sensory properties to the emulsifying characteristics of whey.

Conclusion

Replacing water in bread dough with whey at levels of 25%, 50%, 75%, and 100% increased protein, fat, moisture, and ash contents as the substitution level increased, while carbohydrate content decreased. Dietary fiber content was not affected. With respect to sensory properties, whey substitution significantly affected color, texture, and overall acceptability, whereas taste and aroma were not significantly affected. Overall, whey can be considered a promising water substitute for improving the nutritional value and selected sensory characteristics of bread.

Recommendations

Public health awareness should be increased to encourage consumers to accept whey and whey-fortified products.

Whey should be considered for fortifying baked goods and other foods, and should be made available through local markets so that bakeries can use it.

Guidance booklets should be prepared describing the nutritional and health value of whey and its derivatives, methods of use, places where they are available, and prices, thereby increasing public knowledge.

Higher-education institutions should cooperate with food-manufacturing companies to improve and develop industrial processes for producing affordable foods with high nutritional value while helping to protect the environment from pollution.

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