OPTIMISING THE NUTRITIONAL PROFILE OF BUTTER THROUGH ENRICHMENT WITH CACTUS POWDER: AN INNOVATIVE SOLUTION FOR THE FOOD INDUSTRY

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Abstract

In the context of growing concerns around health and nutrition, this research focuses on enhancing the nutritional profile of butter by incorporating cactus powder, an ingredient known for its high fibre and antioxidant content. The study compares the chemical, nutritional, and phytochemical composition of plain butter with butter enriched with cactus powder, assessing the impact of this addition on various physical and chemical properties. The results show that the enriched butter exhibits higher protein content (1.48%) and non-fat solids (4.34%), while the fat and moisture values remain similar to those of plain butter. Phytochemically, the addition of cactus powder led to a significant increase in carotenoids (81.43 µg/g d.m.), flavonoids (1.16 mg EC/g d.m.), and polyphenols (1.91 mg GAE/g d.m.), thus improving the antioxidant potential of the final product, with a free radical inhibition capacity of 60.11%. These findings suggest that cactus powder-enriched butter could contribute to the diversification of healthy food products available on the market, offering a food item with enhanced nutritional value and functional benefits.

Key words: cactus powder, antioxidant potential, nutritional value, enriched butter, food enhancement

Butter, an essential dairy product, obtained through physical processes from milk, cream, yogurt or secondary products such as whey, is one of the most valuable components of milk, both economically and nutritionally. Being a high-fat product, butter plays a significant role in nutrition due to its unique fatty acid composition and the low melting point of milk fat, facilitating easier digestion and providing a high physiological value (Usturoi M.G., 2022).

According to the Turkish Codex Alimentarius standards (Communication No. 2005/19), butter must contain between 80% and 90% milk fat, up to 2% skimmed milk powder and a maximum water content of 16% of its total weight. This composition makes butter easy to digest and a valuable source of energy for the body. As the world's population grows, the demands on food production, including butter, are becoming more stringent, requiring efficiency and quality in the production process.

According to the World Health Organization (WHO), food fortification is an effective and rapid approach to increase the dietary intake of nutrients in large populations without requiring major changes in dietary behavior (WHO, 2006).

In recent years, interest in healthy foods has increased markedly. Consumers prefer low cholesterol, low-fat, low-calorie and high-fiber foods. There are many studies about the effects of fiber in humans (Alsubhi M. *et al,* 2023) the trend is to search for new, natural sources of dietary fiber for the development of food ingredients. *Opuntia ficus indica* is known for its high content in polyphenols exhibiting antioxidant and anti-inflammatory properties (Kuti J.O., 2004). Therefore, functional ingredients rich in antioxidants, dietary fibers, minerals, and vitamins, low in calories and fat, and free of synthetic additives used in the formulation of conventional foods can enhance their nutraceutical potential. In this context, the composition of *Opuntia ficus indica* cladodes makes it a potential ingredient to produce functional foods that promote health (Aparicio-Ortuño R. *et al*, 2024).

Cactus cladode (*Opuntia ficus-indica*) powder appears to bea promising source to obtain this kind of ingredient. This powder could be considered a natural food supplement to be used in solid or liquid foods (Sáenz C. *et al,* 2010). Powdered cactus is highly valued due to its abundance of antioxidants, high dietary fiber content, and essential minerals and vitamins

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including C and magnesium. It is also free of sugar, low in calories, and high in fiber. These characteristics add to its potential health benefits, which include improved digestion and blood sugar regulation. Because cactus powder works well in both savory and sweet recipes, it's a popular choice for anybody searching for an inventive and healthful ingredient (Monteiro S.S. *et al*, 2023). The study seeks to maximize the nutritional benefits of cactus powder, which is well-known for having a high antioxidant and fiber content. The purpose of this study is to create a butter that has been enhanced with cactus powder to increase its nutritional content and examine the effects of this addition on the phytochemical profile. In addition, we aim to develop a novel product that blends the health advantages of cactus powder with a well-known and digestible meal. By offering new nutrient-rich food options, this study hopes to support a healthier and more sustainable diet and benefit the food sector. This study also assessed the impact of cactus powder on the physicochemical, phytochemicals, texture, and sensory characteristics of butters enriched with cactus powder.

MATERIAL AND METHOD

Regarding the methodology part applied to the research, qualitative analyzes were carried out in the first phase on the raw material, namely the cream. After the cream was processed in order to obtain butter, the technological stages were described and in the last part, the finished products were analyzed from a chemical, phytochemical, physical and sensory point of view.

Determination of total dry matter. The process of oven drying butter at 102°C until a consistent mass is achieved serves as the basis for calculating the total dry material. The process for dealing with an ampoule entails weighing five grams of butter. The butter is combined with sand, stirred, and weighed again. To dry, the ampoules are put in the oven. The sheets are taken out and allowed to cool in a desiccator until the butter has fully dried, at which point they are weighed (Bondoc I., 2014).

Determination of the fat content of sour cream by the butyric acid method. The protein components in the cream are broken down by the sulfuric acid, and the fat is then separated by heating and centrifuging the mixture while it passes through the butyrometer rod and isoamyl alcohol acts upon it.The butyrometer is filled with 10 mL of H2 SO_4 (d=1.820), the cream is well homogenized, and 5 mL is taken with a pipette and put on top of the H_2SO_4. After wiping the butyrometer's neck and adding 1 mL of isoamyl alcohol, seal the butyrometer with a rubber stopper. Mix the ingredients together until the casein clot vanishes. The butyrometer is placed inside the centrifuge and left there for five minutes after mineralization.The butyrometer is set up in a 65–70°C sea bath following centrifugation. The fat reading is done on the butyrometer rod at the top, being expressed in percentages (Bondoc I., 2014).

Determination of titratable acidity. It relies on the neutralization of acids with sodium hydroxide in the presence of phenolphthalein, which is utilized as a color indicator. Therefore, 5 mL of the previously homogenized cream should be placed into the Berzelius glass with the aid of a pipette. After washing the used pipette, put 20–25 milliliters of lukewarm distilled water into the glass. When a pink hue lasts for 30 seconds, add two to three drops of 1% phenolphthalein and titrate with 0.1 n NaOH (Bondoc I., 2013).

The manufacture of butter with cactus powder addition. The first step in making butter is the reception of milk, followed by filtering to remove impurities. To separate cream, 50 L of milk were heated to 45-50°C and gradually introduced into a centrifugal separator with a 12 L capacity. The cream was separated in batches. The cream was then physically ripened at 4-6°C for 6 hours. Three batches were prepared: a control batch of plain cream and an experimental batch with 1% cactus powder *(figure 1)*. After forming the batches, the cream was whipped in a mixer *(figure 2)*, and the resulting whey was removed by draining and washing the butter in cold water with ice cubes (Rațu R.N., Usturoi M.G., 2019).

The butter is washed until all the buttermilk is removed and it hardens. Once fully washed, the butter is molded *(figure 3)* and placed on waxed paper for shaping and packaging. After packaging, it is stored at 0-4°C.

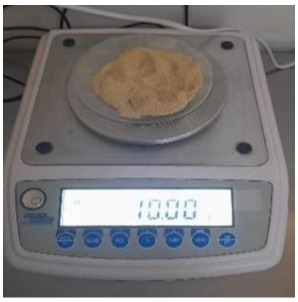

Figure 1 **Weighing the cactus powder**

Figure 2 **Adding the cactus powder to the cream**

Figure 3 **Modeling the butter**

Sensory analysis. From a sensory perspective, the quality parameters were established using the point approach *(table 1*). The point method was used for the sensory examination, the product being analyzed by five tasters who followed the appearance, color, appearance in section, consistency, smell, and taste.

Table 1

Sensory characteristics

Total average score	Qualifying	Product characterization
18.1-20	Very good	The product has positive, specific, well-defined sensory characteristics. It does not have any noticeable defects.
15.1-18	Good	The product has specific positive features that are quite defined, but also very small, insignificant defects.
12.1-15	Satisfactory	The product has poorly outlined specific characteristics, but also small defects due to which it is at the level minimum allowed by the product standard.
7.1-12	Unsatisfactory	The product has defects due to which it is below the minimum quality in the product standard.
4.1-7	Bad	The product has major defects, due to which it is unsuitable for consumption.
0-4	Very bad	Altered product, unsuitable for consumption

In the part of qualitative analyses, sensory, physico-chemical, phytochemical analyzes were carried out in order to establish the qualitative parameters of the samples obtained with the addition of cactus powder as well as of the control sample, according to the AOAC methods.

Phytochemical analysis of butter

Extraction methodology. The study offers a successful procedure for physiologically active compounds extraction that makes use of a 3:1 solvent mixture of n-hexane and acetone. To maximize chemical release, two grams of powder were combined with solvents and sonicated for 40 minutes at 40°C. To separate the liquid from the solid phase, the mixture was centrifuged at 5500 x g for 10 minutes at 4°C. After going through four rounds of repeated extraction, the supernatant was concentrated at 40°C using a rotary evaporator. The quick and pure extraction of physiologically active substances using this approach has shown to be successful; it can be used in food technology, biochemistry, and medicines.

Methodology for determining the total content of flavonoids using spectrophotometry. This section describes the flavonoid quantification procedure according to the method of Dewanto et al. (2002). In this regard, 0.250 mL of the diluted extract (1:10) was mixed with 1.25 mL of distilled water and 0.075 mL of 5% sodium nitrite solution. After five minutes, 0.15 mL of 10% aluminum chloride was added, allowing the mixture to react for 6 minutes. The reaction was neutralized with 0.5 mL of sodium hydroxide 1 M, and the optical absorbance was measured at 510 nm using a spectrophotometer. Total flavonoid concentration was determined using a catechin standard curve, with results expressed as mg EC/g dm.

Evaluation of the content of total phenolic compounds by Folin-Ciocâlteu method. The Folin-Ciocâlteu method for calculating total phenolic compounds in extracts is explained in this section. After adding 1 mL of Folin-Ciocâlteu reagent and 15.8 mL of distilled water to 200 µL of extract, the total volume was 17 mL. Ten minutes later, three milliliters of 20% sodium carbonate were added, and the mixture was left to incubate for sixty minutes at 25°C in the dark. A UV-VIS spectrophotometer was used to detect absorbance at 765 nm. The results allowed for a standardized comparison of the phenolic content between samples because they were represented in milligrams of gallic acid equivalents (GAE) per gram of dry matter (dm).

The methodology for determining the antioxidant activity using DPPH. The DPPH technique was employed in the study to assess antioxidant capability. To obtain a 100 mL stock solution, 25 mg of DPPH was dissolved in methanol. This solution was then further diluted 1:10 to obtain the working solution. Concurrently, a TROLOX stock solution (25 mg in 50 mL 10% ethanol) was made, with concentrations for the standard curve ranging from 1.25 to 25 µM. Included in the reaction volumes were:100 µL of plant extract coupled with 3.9 mL of DPPH solution. Control: 3.9 mL of DPPH solution mixed with 100 µL of 10% methanol. After 90 minutes in the dark, the absorbance at 515 nm was measured, demonstrating the degree of antioxidant activity and the solutions' capacity to lower the DPPH radical.

Texture analysis. was determined using a MARK-10 texturometer (USA) equipped with a series 5 dynamometer, having a maximum capacity of 250 N (25 kgf) and a resolution and accuracy of 0.01 N *(figure 4)*.

Figure 4 **Request to cut a sample of butter**

RESULTS AND DISCUSSIONS

In order to guarantee a high quality finished product, the cream used to make the butter must be of a certain quality *(table 2)*. The average water content of cream was measured at 56.16±0.05%, while the average dry matter value was 43.84±0.01%. These figures show that the composition of the cream is ideal because they are balanced. To guarantee the fluidity of the cream and to facilitate the process of fat separation during butter formation, an adequate water content is necessary.

From *table 2* it can be seen that the average protein value was 2.37±0.01%, which means that it can improve the quality of the cream and at the same time it can help in the process of beating and separation of fats. Fat content averaged 31.95±0.05%, with a range of variation between 32.06% and 31.80%. This fact can help the finished product have a rich texture and remarkable stability, making it perfect for making butter. Regarding acidity, it has an average value of 17.04±0.31.

Table 2

Chemical analysis results for cream

Specify	N	$X \pm s_X$	V%	Min	Max
Water %	5	56,16±0,05	0,31	31,80	32,06
Dry matter %		43,84±0,01	0,07	43,80	43,88
Fat %e		31,95±0,05	0,31	31,80	32,06
Protein %		2,37±0,01	0,81	2,35	2,40
Acidity (°)		17,04±0,31	4,12	16,20	18,10

The outcomes for simple butter are shown in the *table 3*. The acquired data indicates that the average water content value was 13.64±0.014% and the average total dry matter value was 86.36±0.014%. The average value obtained for the protein content was 1.34±0.005%, and the average fat content was 82.50±0.006%, with 82.48% and 82.52% as the limits of variance.

Table 3

Chemical results of plain butter

Specify	Values of Reference	N	$\bar{X} \pm s_X$	V%	Min	Max
Water +Non-fat dry matter	17	5	17,5±0,006	0,08	17,48	17,52
Water (%)	16		13,64±0,014	0,22	13,60	13,67
Dry mattter (%)	84		86,36±0,014	0,04	86,33	86,40
Non-fat dry matter	1		3,86±0,014	0,79	3,83	3,90
Protein (%)	0,7		1,34±0,005	0,85	1,32	1,35
Fat (%)	83		82,50±0,006	0,02	82,48	82,52

Table 4 shows the results obtained for the chemical composition of the butter with the addition of cactus powder, highlighting the following values: the combined content of water and non-fat dry substance has an average value of 17.71 ± 0.03%, with an average water content of and a total dry matter of 86.63 ± 0.01%.

These data reflect the impact of the addition of cactus powder on the chemical composition of the butter, showing minor changes compared to plain butter. Therefore, in terms of water and dry matter content, the reference value for butter is 17%, the average values we obtained being 17.5±0.006% for plain butter and 17.71±0.03% for butter with cactus powder.

Table 4

Chemical results of butter with cactus powder

Specify	Values of Reference	N	$\bar{X} \pm s_X$	V%	Min	Max
Water + non-fat dry matter	17	5	17,71±0,03	0,44	17,59	17,80
Water (%)	16		13,37±0,01	0,18	13,35	13,40
Dry matter (%)	84		86,63±0,01	0,03	86,60	86,65
Non-fat dry matter	1		4,34±0,03	1,63	4,24	4,41
Protein (%)	0,7		1,48±0,005	0,77	1,47	1,50
Fat (%)	83		82,29±0,035	0,10	82,20	82,41

It is noted that the butter with the addition of cactus powder has an average value of non-fat dry substance of 4.34%, significantly higher compared to plain butter (3.86%) as well as to the reference value of 1%, indicating a improving the nutritional content by adding cactus powder. The fact that butter with cactus powder has a significantly higher protein content of 1.48% compared to plain butter (1.32%), as well as the reference value of 0.7% indicating an improvement in protein content by adding cactus powder.

The phytochemical profile of plain butter compared to that enriched with cactus powder reveals significant improvements in the bioactive composition and antioxidant potential of the final product. *Table* 5 shows that plain butter lacks carotenoids compared to butter with cactus powder, which has an average value of 81.43 ±1.50 µg/g d.u. These natural pigments, because of their antioxidant qualities, play important roles in immunological and eye health. The product's anti-inflammatory and antioxidant properties are enhanced when the flavonoid concentration rises from 0.49±0.02 mg ec/g s.u. in plain butter to 1.16 ±0.02 mg ec/g s.u. in the one with cactus powder. Because they neutralize free radicals, total polyphenols, with an average value of 1.91 ±0.03 mg EAG/g s.u. in the enriched butter and 0.81±0.04 mg EAG/g s.u. in plain butter, imply a greater potential for cell protection and cardioprotection. Using the ABTS method to assess antioxidant activity, the results indicate a free radical inhibition capacity of 36.81±0.49% in plain butter and 60.11±0.45% in butter with cactus powder. This translates to 687.55± 10.87 µM Trolox/g s.u. and 1186.04±9.84 µM Trolox/g s.u., depending on the type of butter.

These findings suggest that adding cactus powder to butter enhances its nutritional profile and gives it better functionality, promoting it as a novel product with more health benefits.

Table 5

Phytochemical results of butter

Butter samples	Total carotenoids, µg/g dm.	Total flavonoids, mg EC/g dm.	Total polyphenols, mg EAG/ dm.	Antioxidant activity (ABTS),	
				µM Trolox/g dm.	Inhibition, %
Butter	-	0,49±0,02	0,81±0,04	687,55±10,87	36,81±0,49
Butter with cactus powder	81,43 ±1,50	1,16 ±0,02	1,91 ±0,03	1186,04±9,84	60,11±0,45

In terms of average cutting forces, recorded from texturometer tests *(figures 5, 6)*, we can see that for plain butter the cutting force is 2.85N and for butter with 1% cactus powder it is 3.05N. Since the tested butter samples were of the same size and the tests were performed at the same temperature 10.75°C, the difference in cutting force obtained is due to the addition of cactus powder, and this difference is very small at 0.2N.

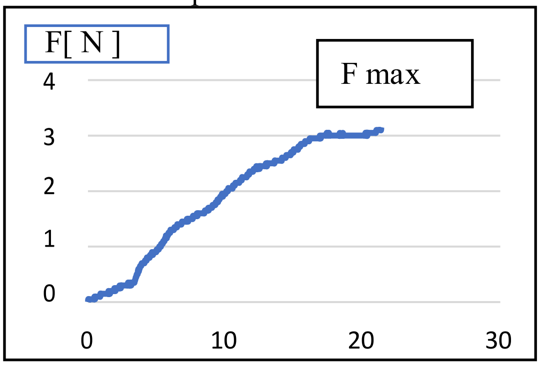

Figure 5 **Maximum cutting force recorded with a plain butter texturometer**

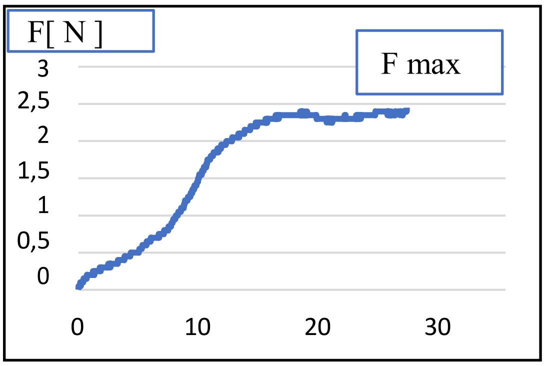

Figure 6 **Maximum cutting force recorded with a texturometer of butter with cactus powder**

The quality of the cream used in butter production is crucial to ensure a high-quality final product. In the interpretation of the results obtained from the sensory analysis of the plain butter and the one enriched with cactus powder, we observe significant differences. *Figure 7* shows us that plain butter has more balanced scores in all categories, but without extreme values. In contrast, in *Figure 8* we can see that the butter with cactus powder obtained higher ratings in terms of smell and taste, which suggests an improvement of these attributes due to the cactus powder. Plain butter scored 17.8 points, reflecting high quality and appreciation for its traditional characteristics. On the other hand, the cactus powder enriched butter scored higher at 18.6 points, reflecting a slightly higher appreciation due to the innovation brought by the addition of cactus powder.

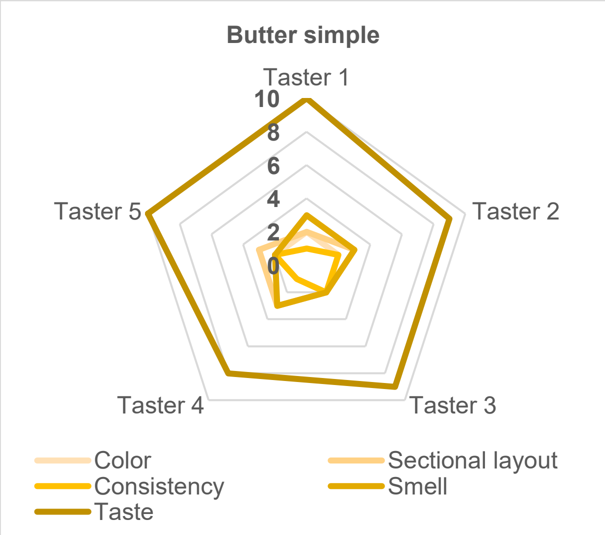

Figure 7 **Sensory evaluation of simple butter**

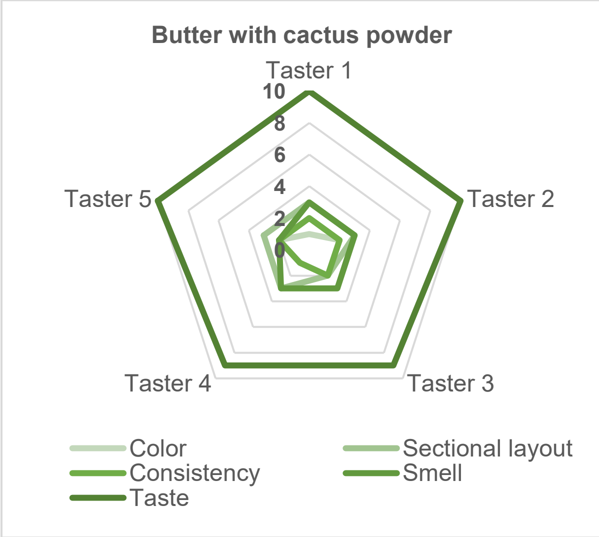

Figure 8 **Sensory evaluation of butter with cactus powder**

CONCLUSIONS

In the modern era, consumers are increasingly interested in food products that offer not only the pleasure of taste, but also health benefits. The sensory acceptability of any food product is a crucial component. The new variety may have been preferred by customers because of its improved taste, texture, and aroma compared to the butter made with cactus powder.

The innovation of adding cactus powder to butter is an important step towards the development of functional food products. This product not only offers a superior taste experience, but also brings significant health benefits due to its high content of antioxidants and nutrients.

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