Functional properties of cladodes flour (*Opuntia ficus-indica*) and sensorial attributes of wheat-cladodes composite bread: Effects of processing methods and blending ratio

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Abstract

The present study aimed to evaluate the effect of pretreatments (unblanched and blanched), temperature (45, 55 and 65℃) and slice thickness (0.5, 1.0 and 1.5 cm) on the functional characteristics of cladodes flour. In addition, a bread product was developed from these cladodes and wheat flours with different blending ratios (95:5, 90:10, 85:15 and 80:20) and control to study the sensory acceptability of the produced bread. Except for oil absorption capacity and bulk density, the selected processing methods significantly ($p< 0.05$) affected the functional properties of cladodes flour. The 1.5 cm thick unblanched samples dried at 45℃ had a relatively higher bulk density of 0.8 g/mL. The 1.5 cm thick unblanched samples dried at 55℃ had high water absorption capacity compared to other combinations or interactions. The blanched cladodes flour sample had a low value of water absorption capacity, and the unblanched cladodes flour had a high value of water absorption capacity. Regarding the sensory evaluation, data revealed that the bread products developed from 5 % formulation and blanched flour were the most accepted in terms of overall sensory acceptability by the panellists.

Keywords: Cladodes flour, Food security, Functional properties, Sensory properties

1. Introduction

Wheat grain (*Triticum aestivum L.*) is an essential cereal grain rich in starch which provides energy for humans and plays a vital role in the production of different food products such as noodles, cakes, cookies bread, and biscuits (Abera et al., 2017; Dziki et al., 2014; Goubgou et al., 2021, 2021; Salem et al., 2024; Wang et al., 2013). Food products made from the cereal grain are widely consumed across the continents due to their low cost, extensively availability, and are easily affordable for the people of the world (Aparicio-Ortuño et al., 2024, Guevara-Arauza et al., 2015). Also, it is naturally rich in gluten, which is essential to increase the loaf volume and elasticity of the wheat flour dough when mixed with ingredients like yeast, baking powder, and water (Abera et al., 2017; Wang et al., 2013). The Gluten network is very crucial in gas formation and formation during wheat dough fermentation in the bakery industry (Dick, Limberger, Silveira Thys, et al., 2020) From a nutritional perspective, micronutrients such as minerals and vitamins in wheat flour are insufficient to alleviate the problem of people suffering from micronutrient malnutrition (Abera et al., 2017; Dziki et al., 2014; Wu et al., 2018).

Cactus pear (*Opuntia ficus indica)* is one of the angiosperm plants of the Cactaceae family that originated in Mexico (Abbas et al., 2022a; De Santiago et al., 2019; Dib et al., n.d.; El-Mostafa et al., 2014; Elshehy & Sayed, 2020a; Jiménez-Aguilar et al., 2015; Maria Stacewicz, 2010; Mounir et al., 2020; Mulu, 2015; Vazquez-Mendoza et al., 2017). After some time, this miraculous plant has been distributed to other parts of the world, such as Brazil, Israel, North Africa, Chile, Italy, and the Mediterranean region like Turkey, by different spreading mechanisms (López-Cervantes et al., 2011; Elshehy and Sayed, 2020b; El-Mostafa et al., 2014; Abbas et al., 2022, de Souza *et al.*, 2015). It is a drought-resistance crop which grows in arid and semi-arid climate regions of the world (Abbas et al., 2022a; Ammar et al., 2015; Aparicio-Ortuño et al., 2024a; Aruwa et al., 2019; Bensadón et al., 2010a; Haile et al., 2017). Despite being one of the most neglected plants, the crop has recently been used for erosion control, foraging for cattle feed, and fighting desertification, one of the most frustrating global issues. Also, it is the most important crop in the cosmetic and pharmaceutical industries (Abbas et al., 2022b). Additionally, the plant is used as a traditional food product which the Mexican people of South America extensively consumed (Ramirez-Moreno et al., 2011). People have consumed this crop in various ways; for example, in Mexico, people consume nopal or cactus pear in salads or fresh and use it as an ingredient in other food items such as snacks, juice, and tortillas (Fabela-Illescas et al., 2022).

Moreover, its flours have been used as nutritional enrichment and supplementation in the food industry, particularly in the bakery industry (Kumar et al., 2022). It has been used as a traditional medicine due to its anti-inflammatory, analgesic, anticancer, cardiovascular supportive, antidiabetic, gastroprotective, hepatoprotective, and nephroprotective properties (Abbas et al., 2022b; Fabela-Illescas et al., 2022; Héliès-Toussaint et al., 2020). This crop's well-known and scientifically ratified bioactive compound is polyphenols, which provide antioxidant activity. The plant offers edible pads containing soluble and insoluble dietary fibres, and prickly pears are a good source of betalains (Chavez-Santoscoy, Gutierrez-Uribe and Serna-Saldívar, 2009). These compounds reduce metabolic endotoxemia, glucose intolerance, lipogenesis and metabolic inflexibility (Fabela-Illescas et al., 2022,). Significantly, the availability of fibre nutritional content in this crop is critical to mitigating the problem of stomach constipation for those suffering from such constraints. Cladodes are also rich in vital minerals. Although this crop is crucial regarding its nutrition and health benefits, there is no attention given to the plant compared to other crops. Therefore, the present study was conducted to overcome the problem of food insecurity and micronutrient malnutrition by formulating wheat flour with cladodes flour obtained from cactus pear (*opuntia ficus-indica*).

In the food industry, functional properties such as water absorption capacity, water solubility index, swelling Power, oil absorption capacity and bulk density play a pivotal role in increasing the acceptability of the product's ingredients on the market. Moreover, they determine and influence the products' physical, chemical, and sensory properties. For instance, bulk density determines the capability and the strength and appropriate packaging materials used for packaging food products, energy density and sensory attributes of the products (Dereje et al., 2020; Reda & Atsbha, 2019).

Hence, the main objective of this study was to: (i). determine the effects of drying temperature, thickness, and pretreatment on the functional properties of cladodes flour (ii) develop a bread from composite flour of wheat and cladodes flour (iii) assess the right drying temperature, slice thickness, and pretreatment methods for cladodes flour production, and (iv) study the effect of pretreatment methods, namely: blanched and unblanched cladodes powder and wheat blending ratio, on the sensory characteristics of bread product.

2. Materials and methods

2.1. Experimental Site

The experiments were conducted at Nigde Omer Halisdemir University, Department of Plant Production and Technologies of Pomology laboratories.

2.2. Experimental Material

Cladode leaves used in these experiments were collected in a plastic bag from Mersin Tarsus, the Mediterranean region of Turkey, where it had been naturally wild-grown.

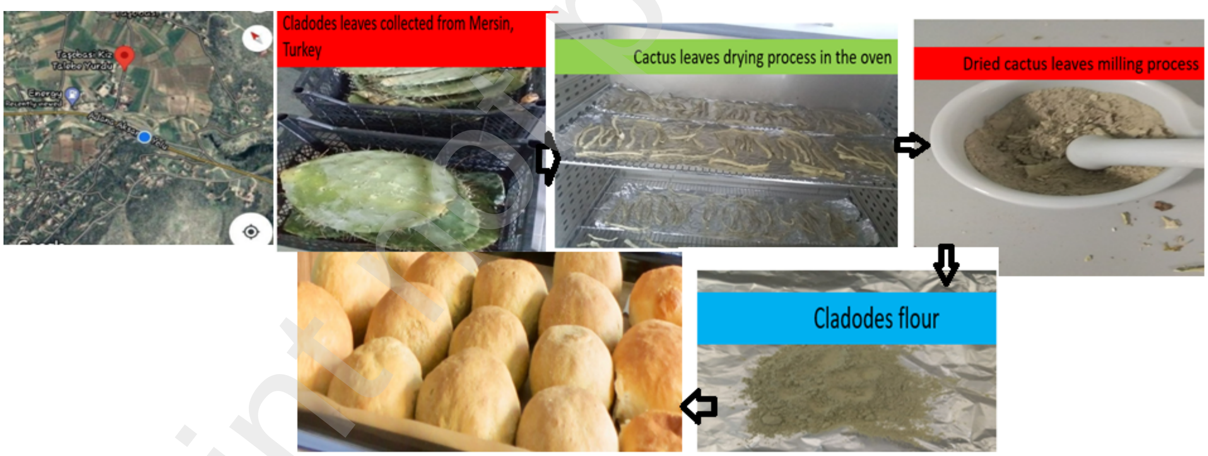

Figure 1. Collection of cactus pear (*Opuntia ficus indica*) from Mersin, Turkey

2.3. Experimental design

The experiment was conducted using a complete factorial design with three factors in a factorial arrangement of 3x3x2. These factors are the drying temperature of the sliced cladode at (45, 55, and 65 ^{0}C), the thickness of the cladode (0.5, 1, and 1.5cm), and pretreatment (blanching and un-blanching) (Table 1). The first and the second factors were within three levels, and the third factors were within two, respectively. The blanching time was two minutes at 95 ^{0}C then cladodes drying was carried out in the oven drying method. For the product development, a 2x4 factorial with three replications was used (Table 2). The two factors were wheat–cladodes flour blending ratio and pretreatment methods of cladodes flour, which contains four and two levels, respectively.

Table 1. Experimental design for cladodes processing

		Pretreatment	
Drying temp.	Thickness	B	UB
45	0.5	450.5B	450.5UB
45	1	451B	451B
45	1.5	451.5B	451.5UB
55	0.5	550.5B	550.5UB
55	1	551B	551UB
55	1.5	551.5B	551.5UB
65	0.5	650.5B	650.5UB
65	1	651B	651UB
65	1.5	651.5B	651.5UB

Where: UB= Unblanched cladodes and B= blanched cladodes

Table 2. Treatment combinations for the bread-baking process

	Blending ratio (B) (%)			
Pretreatment	B1	B2	B3	B4
B	BB1	BB2	BB3	BB4
UB	UBB1	UBB2	UBB3	UBB4
Wheat (100%)	control			

Where: B = Blanched cladodes flour, B1 = Blending ratio 1 (5 g cladodes flour/100 g wheat flour) UB = Unblanched cladodes flour, B2 = Blending ratio 2 (10 g cladodes flour/100 g wheat flour) B3 = Blending ratio 3 (15 g cladodes flour/100 g wheat flour, B4= Blending ratio 4 (20 cladodes flour/100 g wheat flour, C = Control (100 g wheat flour).

Sample preparation and cladodes flour production

The cladodes were cut gently with a sharp knife, and the spines were separated clearly from the cladodes' surface using eyeglasses and hand gloves. Then cladodes were cleaned with tap water. Excess water on the cladode surface was removed with absorbing paper. Then after the cladode was sliced according to the given thickness of 0.5, 1, and 1.5 cm, using a digital calliper, the initial weight of each cladode thickness was measured using the sensitive electronic balance. The unblanched or untreated cladodes were cut into pieces and dried according to their thickness in each drying temperature, i.e., 45, 55, and 65℃, according to (Lahsasni et al., 2004; Moreno-Castillo et al., 2005) who made drying kinetics of nopal at a temperature of 45℃ and 65℃ and airflow at 3 and 5 m/s. The second pretreatment was blanching by immersing in hot water at 95 ℃ for 2 minutes.

The blanched sample was dried in the oven drying method at 45, 55, and 65 ℃. The weight of the samples was determined periodically at an interval of 15 minutes initially up to about six hours and 30-minute afterwards as the weight change was less. The initial moisture content was about 94%, and the final was around 7% (d.b). At the end of this process, the dried cladode was milled using a Sinbo machine miller and mortar and pestle as well to pass through a 0.45mm sieve and adequately packed in a plastic bag using an electrical sealer (Reda & Atsbha, 2019). The sealed powder was kept in polyethylene bags and stored at room temperature until required for the experiment.

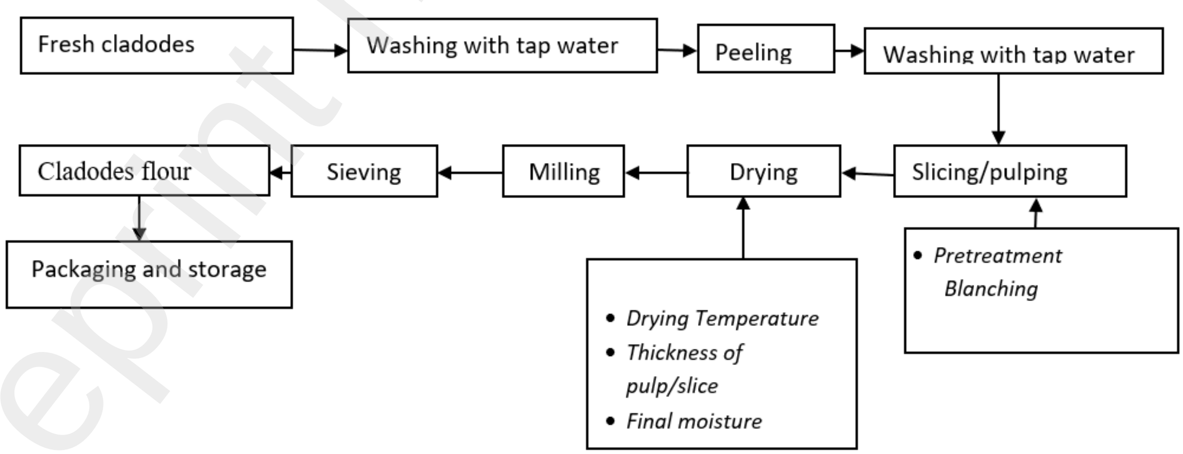

Figure 2. Flow diagram for preparation of cladodes flour.

Source (El-Safy, 2013)

2.4. Bread making

Bread was baked straight dough methods as described in the AACC (2000). It was made with the ingredients wheat-cladodes flour (500g) according to their blending ratios, water (450ml), salt (6g), yeast (6g) and 6g of baking powder.

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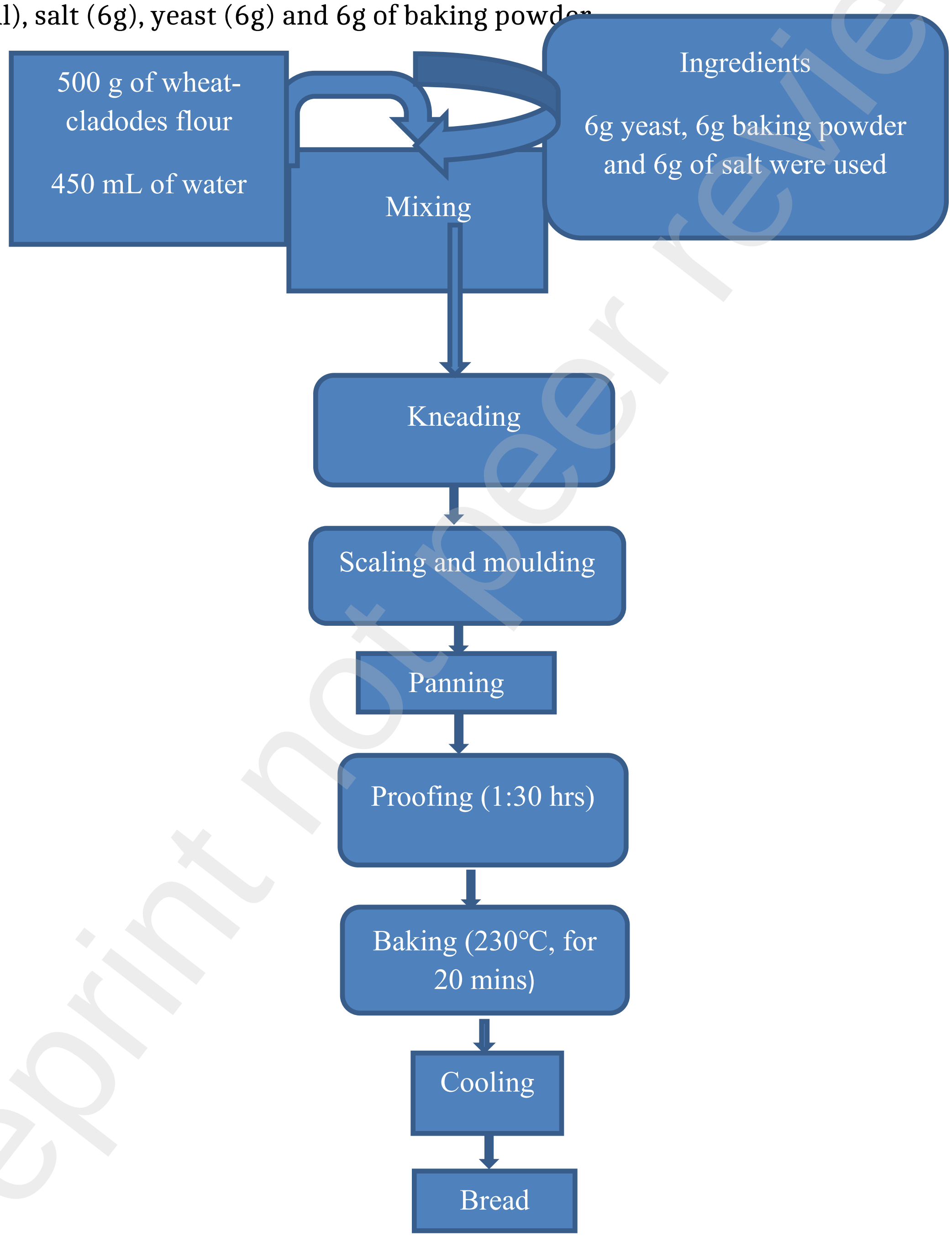

Figure 3. Flow chart for Bread baking process

Functional properties of Cladodes flour

2.4.1. Water absorption capacity

Water absorption capacity was determined in accordance with the method described by Korese, (2022) with little modifications. About 1 g of powdered sample and 10 mL of distilled water were thoroughly mixed and allowed to rest for 30 minutes before centrifuging at 3000 rpm for 15 minutes (Korese, 2022). The water absorption capacity was calculated as shown in the equation.

Water absorption capacity (mL/ g) = $\frac{initial\ volume(10ml) - volume\ left(ml)}{weight(g) of\ powder}$

2.4.2. Oil absorption capacity

First, 1.00 g of sample was added with 10mL of corn oil in a beaker. Then, the suspension was stirred using a magnetic stirrer for 5 minutes. After that, the suspension was centrifuged at 3600 rpm for 30 minutes. The supernatant produced was measured in a 10mL graduated cylinder. Oil absorption was then calculated as the difference between the initial volume of the oil added and the volume of the supernatant. The result was stated as millilitre per g of powder (mL/ g) (El-Safy, 2013).

2.4.3. Swelling Power

Swelling Power was determined based on the method stated by (El-Safy, 2013). First, 1.00 g of powder was weighed and inserted into a pre-weighed centrifuge tube. Then, 10 mL of distilled water was added into the centrifuge tube and mixed well. After that, the tube was heated at 80 ^{0}C for 30 minutes (in a hot water bath) with continuous shaking during the heating period. After heating, the suspension was centrifuged at 2280 rpm for 15 minutes, then the suspension was-decanted and the weight of the centrifuge tube and the paste was measured. The swelling Power was calculated by dividing the weight of paste by the weight of the dry sample. The result was expressed as gram per gram (g / g).

2.4.4. Bulk density

A 50.00 g flour sample was put into a 100 mL measuring cylinder. The cylinder was constantly tapped on a laboratory bench to a constant volume. The volume of the sample was recorded.

Bulk density $(g/mL) = \frac{Weight\ of\ sample}{Volume\ of\ sample\ after\ tapping}$

2.4.5. Water solubility index

The supernatant preserved from the water solubility index measurement was subjected to an evaporation process in a drying oven at 105°C for a prolonged period. The main objective of this process was to remove all the water present in the supernatant to obtain dry residue. Once the evaporation process is completed and the supernatant has completely dried, the weight of the dry residue was measured. This weight was then compared to the original mass of the flour sample used for the WSI measurement. The dry residue weight ratio to the flour sample's original mass used to estimate WSI was then calculated. This ratio was expressed as a percentage, as per the method described by Aderson et al. (1969). The supernatant obtained from water solubility index measurement was evaporated at 105°C overnight in a drying oven. The WSI was calculated as a ratio of dry residue to the original mass used to estimate WSI. The results are expressed as percentage (Anderson *et al.*, 1969).

$$WSI\ (\%) = \frac{Wr}{WS} * 100$$

Where wr = is the weight of residue supernatant after evaporation (g) Ws = weight of the sample (g)

2.5. Sensory properties

Sensory evaluation was conducted by randomly selecting 60 trained panellists from the Plant Production and Technologies department of Nigde Omer Halisdemir University's senior students and staff. Individual panellists were requested to read and sign an informed consent form. The panellists were asked to evaluate the descriptors, rating each sample on a 7-point Hedonic scale. The baked bread product slices were analyzed for colour, flavour, taste, texture, aroma, and overall acceptability. The sensory scale included: like extremely =7, and dislike extremely =1.

2.6. Data analysis

Statistical analysis was carried out using the software package SAS (SAS Institute, Inc., Cary, N C, USA) version 9.0 by using analysis of variance (ANOVA) for a completely randomized design with the factorial arrangement. The results were reported as an average value of triplicate analysis of (mean ± SD). Fisher's Least Significance Difference (LSD) test at the significance level of 5% was used to determine significant differences among the samples.

3. Results and Discussions

3.1. Functional properties

As indicated in Table 3, the effect of the different factors or treatments on the functional properties of *cladodes flour* has been reported. Overall, the treatments had a significant ($p < 0.05$) effect on most of the functional properties, except for oil absorption capacity (OAC) and bulk density (BD). It was observed that oil absorption capacity was significantly ($P<0.05$) affected by pretreatment and temperature but not significantly ($P>0.05$) affected by thickness and the combination of the factors (Table 3). Regarding bulk density, there was a main pretreatment, slice thickness and temperature effect, while slice thickness, pretreatment, and temperature had a marked interaction effect. However, OAC values ranged between 0.63 ± 0.03 mL/g in 1.0 cm treated or blanched samples dried consistency at 55 ℃ to 1.1 ± 0.05 mL/g in 0.5cm unblanched samples dried at 45 ℃ was while bulk density varied between 0.45± 0.005 g/mL in 1.5 cm unblanched samples and 0.8 ± 0.21 g/mL in 1.5 cm blanched samples both dried at 45 ℃. Oil absorption capacity is one of the functional properties of food materials used to determine or evaluate the hydrophobic nature or water dislike of food products. Notably, it is essential to assess the food particles contained by fibre fraction, which is related to the emulsifying properties of food materials. Also, the oil absorption capacity is essential, because oil plays a pivotal role in increasing the mouthfeel while evaluating the sensory attribute of food products, particularly when determining flavour sensory characteristics.

The current study revealed that the result (Table 3) showed that the oil absorption capacity of cladodes flour was 1.1 mL/g, the obtained value was lower than the value reported by (Reda & Atsbha, 2019), which was 1.45 mL/g and of El-Safy (2013), 2.8 mL/g. The oil absorption capacity of the cladodes might be different compared to the value obtained by other authors due to the variety and age of cladodes, the degree of milling of the flours and the drying conditions in addition to environmental conditions (El-Safy, 2013). Additionally, bulk density is one of the most critical functional properties used to select the appropriate packaging materials according to the volume of the food products. This means the increased bulk density is a sign of packaging advantages as more flour powder occupies a given volume of space. However, it undisputedly indicates more transportation costs (Korese, 2022). As seen from Table 3, the present study suggested that the value of bulk density of cladodes flour is 0.45- 0.8 g/mL.

Table 3. Effect of slice thickness, pretreatment, and temperature on functional properties of cladodes flour

Temp (°C)	Pretreatment	Thickness (cm)	Water absorption capacity (mL/g)	Water solubility index (%)	Swelling Power (g/g)	Oil absorption capacity (mL/g)	Bulk density (g/mL)
45	Blanched	0.5	1.9±0.04fg	32.5±2.5^{bcd}	5.5±0d^{e}	0.76±0.04^{cdefg}	0.62±0.02^{bcdef}
		1	2.09±0.43^{fg}	37.5±2.5^{abc}	5.75±2.5^{de}	0.67±0.045^{efg}	0.64±0.02^{bcde}
		1.5	1.86±0.41^{fg}	30±5^{cd}	5.0±0^{e}	0.845±0.2^{bcdef}	0.8±0.21^{a}
	Unblanched	0.5	3.07±0.096^{de}	30±0^{cd}	6.25±2.5^{cd}	1.1±0.05^{a}	0.46±0.02^{gh}
		1	4.94±0.52^{ab}	27.5±2.5^{d}	5.75±2.5^{de}	0.87±0.03^{bcd}	0.5±0.001^{efgh}
		1.5	5.31±0.065^{a}	25.5±0d	7.5±5^{b}	0.98±0.02ab	0.45±0.005^{h}
55	Blanched	0.5	2.09±0.16^{fg}	32.5±2.5^{bcd}	6.0±5^{cde}	0.705±0.065^{defg}	0.64±0.001^{bcde}
		1	2.28±0.28^{f}	32.5±2.5^{bcd}	6.0±5^{cde}	0.63±0.03^{g}	0.7±0.002^{ab}
		1.5	1.39±0.015^{hg}	37.5±2.5^{abc}	6.25±2.5^{cd}	0.77±0.08^{cdefg}	0.61±0.005^{bcde}
	Unblanched	0.5	2.16±0^{f}	32.5±2.5^{bcd}	6.0±5^{cde}	0.9±0.055^{bc}	0.5±0.02d^{efg}h
		1	4.25±0.5^{bc}	32.5±2.5^{bcd}	6.0±0^{cde}	0.885±0.035^{bc}	0.5±0.01^{fgh}
		1.5	5.35±0.05^{a}	27.5±2.5^{d}	6.25±2.5^{cd}	0.95±0.01^{ab}	0.5±0.004^{efgh}
65	Blanched	0.5	2.24±0.025^{f}	37.5±2.5^{abc}	5.75±7.5^{de}	0.66±0^{g}	0.7±0.002^{abc}
		1	1.89±0.006^{fg}	32.5±2.5^{bcd}	6.0±0^{cde}	0.695±0.01^{efg}	0.67±0.002^{bcd}
		1.5	1.13±0.023^{h}	40±0^{a}	5.25±2.5 ^{de}	0.685±0.055^{fg}	0.62±0.009^{bcdefg}
	Unblanched	0.5	3.61±0.07^{cd}	45±0a	5.5±5de	0.87±0.02^{bcd}	0.55±0.02^{bcdefgh}
		1	3.72±0^{cd}	27.5±2.5^{d}	7.0±5^{bc}	0.855±0.055^{bcde}	0.54±0.003^{cdefgh}
		1.5	2.43±0.11^{ef}	25±5^{d}	8.75±2.5^{a}	0.85±0.04^{bcdef}	0.5±0.02^{fgh}
Effects							
Slice thickness (ST)			**	**	*	NS	NS
Pretreatment (P)			**	**	**	**	**
Temperature (T)			**	*	*	**	NS
STXP			**	**	**	NS	NS

STXT			**	**	*	NS	*
PXT			**	NS	**	NS	*
STXPXT			**	**	**	NS	*

Where: NS represents insignificant and *and ** represent p-value <0.05, <0.0001, respectively. Values (mean ± standard deviation) with different superscripts in the same column are significantly different.

The obtained value is consistent with the results of (Korese, 2022; Reda & Atsbha, 2019). Swelling Power is one of the functional properties of food products that measures a powder's hydration capacity (El-Safy, 2013) This is due to the swelling Power measuring the weight of swollen starch granules and their occluded water (El-Safy, 2013). This measure is essential because food-eating quality is often connected with water retention in the swollen starch granules (El-Safy, 2013). In this study, swelling Power had significantly been affected (P<0.05) by the treatments' main effect and interaction. The values obtained ranged from 5.0 ± 0 g/g in 1.5 cm blanched samples dried at 45℃ to 8.7 ± 2.5 g/g in 1.5 cm unblanched samples dried at 65 ℃. This showed that steam blanching and low-temperature application decrease the swelling Power of the cladodes flour, and as temperature increases, the swelling Power of the cladodes flour also increases. The same explanation was presented regarding the impacts of the treatments or factors (Korese, 2022), who did the study on fruit powder.

The result shown in Table 3 is in agreement with (El-Safy, 2013). However, it disagreed with (Korese, 2022) more than the current study result (9.12–15.68 g/g). This variation might be due to different factors such as climatic change, the variety of cactus pears and other environmental conditions. Water absorption capacity (WAC) is one of the functional properties used to determine the food products' water-holding ability, particularly in the baking industries, such as the cake and bread industries. High water absorption capacity values indicate weak amylose-amylopectin linkage or imply the unbranched and branched structure of the polysaccharides, respectively, which speed up water permeability into the granular systems (Korese, 2022). It is a vital property for product bulking and consistency in the food industry, with high WAC samples highly accepted for baking applications (Korese, 2022).

Water absorption capacity was significantly (P < 0.05) affected by all the factors and their combinations (Table 3). Water absorption was lowest (1.13mL/g) in 1.5 cm blanched or treated by hot water samples dried at 65 °C and highest (5.35 mL/g) in 1.5 cm unblanched samples dried at 55 °C. In terms of the main effect, as temperature and pretreatments or unblanched cladodes are used, and slice thickness increases, the water absorption capacity of the cladodes flour was also increased. This study's result (Table 3) showed that the value of cladodes flour's water absorption capacity ranges from 1.13 to 5.35 mL/g, which is agreed with El-Safy (2013), who obtained 4.5 mL/g. Therefore, due to its high-water absorption capacity, cladodes flour is one of the best and most valuable raw materials in the food industry, especially in the baking industry.

The water solubility index (WSI), the WSI is one of the functional properties of food materials, which is used to determine the number of polysaccharides released from the starch granules. In the present study, Table 3 showed that the WSI was significantly (P<0.05) affected by pretreatment, slice thickness, temperature and their combinations. However, it had not significantly (P> 0.05) affected by pretreatment and temperature interactions. The water solubility index was lowest (25.5%) in 1.5 cm unblanched samples dried at 45°C and highest (45 %) in 0.5 cm unblanched samples dried at 65 ◦C. In terms of the main factor effect, this study revealed that a high WSI was obtained by applying treatments, such as using unblanched pretreatments, decreasing thickness and increasing the temperature on the cladodes flour.

3.2. Sensory Evaluation

The seven points hedonic scale was used to assess and evaluate the sensory attributes of bread products formulated from wheat-cladodes composite flour acceptability viz colour, flavour, taste, texture, aroma, and overall acceptability as indicated in Table 4. The sensory results indicated that the color of blanched bread products had significantly increased (P<0.05) as compared to the unblanched cladodes flour which scored 5.3. Except flavor sensory attributes which had not been significantly (P>0.05) affected by pretreatments, the pretreatments methods were signifactly increased (P<0.05) the sensorial attributes of the bread products as shown in Table 4. All cases blanched or treated samples were the most acceptable ones to increase the sensory attributes of the products as compared to the untreated or unblanched samples.

Considering the sensory characteristics, bread made from blanched cladodes flour dried at 45℃ and sliced to thicknesses of 0.5 and 1cm, along with bread made from 65℃ dried cladodes flour sliced to a thickness of 0.5, showed higher acceptability compared to bread made with unblanched flour. Statistically, in terms of the colour of the product, the hedonic test result revealed that the blanched and unblanched pretreatments had significantly ($P< 0.05$) affected the colour of bread products. This means the blanched product scored 5.32, the highest, and the unblanched one scored 4.87 out of seven hedonic scales. The mean values of the colour of products formulated from blanched and unblanched cladodes flour ranged from 5.32 to 4.87, as shown in (Table 4).

Scientifically elaborating on these attributes, the main purpose of blanching is to inhibit or retard the enzymatic browning in fruit and vegetables, which brings an undesirable change in the sensory characteristics of the food products, such as colour, flavour, taste, texture, and aroma. Hence, with this results point of view, blanched cladodes flour is vital to intensify the sensory attributes of the bread products compared to those formulated from unblanched cladodes. So, the panellists liked the blanched product compared to the unblanched product (Table 4).

Table 4. The sensory acceptability of bread products as affected by pretreatments methods such as blanched and unblanched cladodes flour

Pretreatment methods	Colour	Flavour	Taste	Texture	Aroma	Overall acceptability
Blanched	5.3±1.28^{a}	5.6±1.21^{a}	5.4±1.16 ^{a}	6.0± 1.22^{a}	5.3± 1.41^{a}	5.47± 1.13^{a}
Unblanched	4.8± 1.75^{b}	5.5±1.42^{a}	4.7± 1.6 ^{b}	5.44± 1.58 ^{b}	4.75± 1.70 ^{b}	4.82± 1.56^{b}
LSD	0.35	0.30	0.32	0.32	0.35	0.31

Values were means ± SD, and values in the same column with different superscript letters significantly differed ($P < 0.05$).

The effects of cladodes blending ratio on sensory acceptability of cladodes- wheat composite bread products were evaluated using a 7-point hedonic scale (Table 5). Significant differences ($p < 0.05$) were observed on the sensory assessed parameters (colour, texture, aroma, taste, texture, and overall acceptability) among the treatments and control bread product samples formulated from cladodes- wheat composite flour samples. The Panelist's acceptability for colour, taste, aroma, flavour and overall acceptability of the samples significantly ($p < 0.05$) decreased with an increased level of cladodes flour blending ratios except for texture sensorial attributes, which were increased at 15% blending ratio of cladodes flour as compared to 5% blending ratio. The flavour and texture of the cladodes formulated with a 5% cladodes powder blending ratio were most preferred, scoring 6.17 and 6.27, respectively and liked moderately. The control (100g wheat flour) bread sample of cladodes- composite wheat flour was the most acceptable. The same trend was observed for aroma, taste, flavour and texture in that acceptability of bread sample decreased with the increased proportion of cladodes powder blending ratio.

Regarding the results obtained for the colour sensory attributes, the bread products' colour was significantly affected by blending ratios ($P<0.05$). There was a decrease in the colour of bread products with an increasing level or percentage of cladodes flour. Compared to the blending ratios such as 5,10,15, and 20% samples, the control bread samples with 100% wheat flour significantly increased ($P < 0.05$) in colour, flavour, taste, texture, and aroma acceptability of the products. Regarding the aroma of bread samples formulated from cladodes-wheat composite flour, there was a significant difference ($P< 0.05$) between control (0 g of cladodes flour), 5% and 20%. However, there was no significant ($P>0.05$) difference between the 10% and 15% blending ratio of cladodes flour. The acceptability of the taste of bread samples showed significant differences between the 5g and 10g cladodes flour blending ratio and the control of bread samples. The bread product samples tasted processed by 0g, and 5g of cladodes flour blending ratio was evaluated as the most preferred (closely liked moderately). The texture of the bread products samples processed by cladodes powder blending ratio of 0 g and 5g showed no significant difference (P >0.05) as they were both more preferred by the panellists, which scored 6.57 and 6.25, respectively. Most importantly, the texture of bread products formulated from 10 and 15% was the most preferred by the consumers over the samples formulated from 5%, which scored 5.63 and 5.32, respectively. The rating for overall acceptability of the bread product formulated from 5 and 10% cladodes flour was significantly higher and evaluated as "liked moderately and slightly respectively" than the other samples. Overall, consumer acceptability decreased with a higher level of cladodes powder blending ratio.

Table 5. The effect of blending ratios such as 100:0 (control), 95:5, 90:10, 85:15 and 80:20 on sensory acceptability of bread product

Blending Ratio (%)	Colour	Flavour	Taste	Texture	Aroma	Overall acceptability
0	6.08 ± 1.23^{a}	6.63 ± 0.66^{a}	6.05 ± 1.21^{a}	6.57 ± 0.93^{a}	6.15 ± 1.12^{a}	6.12 ± 0.88^{a}
5	5.72 ± 1.15^{a}	6.17 ± 0.85^{b}	5.68 ± 0.89^{a}	6.27 ± 0.88^{a}	5.55 ± 1.25^{b}	5.73 ± 0.86^{a}
10	4.93 ± 1.45^{b}	5.43 ± 1.21^{c}	4.95 ± 1.39^{b}	5.63 ± 1.28^{b}	4.86 ± 1.44^{c}	4.95 ± 1.37^{b}
15	4.68 ± 1.41^{b}	5.12 ± 1.15^{c}	4.57 ± 1.38^{bc}	5.32 ± 1.51^{bc}	4.61 ± 1.38^{c}	4.70 ± 1.24^{b}
20	4.01 ± 1.60^{c}	4.53 ± 1.44^{d}	4.13 ± 1.52^{c}	4.93 ± 1.78^{c}	3.93 ± 1.73^{d}	4.24 ± 1.62^{c}
LSD	0.49	0.39	0.47	0.47	0.50	0.44

Values were means ± SD and values in the same column with different superscript letters significantly differed (P < 0.05).

The sensory attributes of bread products scores for colour sensory characteristics are presented in Table 6. The pretreatment method, namely, blanched and unblanched, significantly (P<0.05) affected the colour of the cladodes- wheat composite bread. The colour difference of cladodes–wheat bread due to blending ratios (Table 5) was significant (P < 0.05) different. There was no significant (P>0.05) difference in the colour of the bread due to the blending ratio and the interaction between the pretreatment method and the blending ratio. However, there was a general decreasing trend in the score with increased cladodes flour pretreatment under blanched and unblanched flour. The highest score (6.08, liked moderately) was observed for the control sample. Among the experiments, the highest score

of 5.72 (which was almost close to liked moderately) was observed for blanched cladodes flour and 5% blending ratio samples and 3.33 (disliked moderately) was for unblanched cladodes flour and 20% blending ratio cladodes composite flour of bread products. The same result was reported by Abera et al. (2017); 100% of the panellists preferred the control (100% wheat) compared to cladodes-wheat flour composite bread. The colour difference can be contributed by the browning reaction that occurs during pretreatment methods, particularly for untreated or unblanched cladodes flour. The consumers or panelists lacked expertise in consuming bread made by bread blending green-colored flour from cladode.
The results of the sensory taste scores are presented in Table 6. There was a significant difference ($P < 0.05$) in the taste of bread due to the blending ratio, pretreatment methods and the interaction between the blending ratio and the pretreatment methods. As shown in Table 6, there was a general decrease in the taste score with an increase in cladodes flour proportion. The highest score was 6.2 (liked moderately) for control samples. The least scores were obtained for unblanched samples and with cladodes proportion of 20%. The same studies were reported by (Abera et al., 2017), who obtained a similar result by conducting on taro-wheat composite flour. This might be due to the availability of calcium oxalate contents in the cladodes flour, which contributes to the salty taste of the blended bread (Abera et al., 2017; Hernández-Becerra et al., 2022).

Texture is one of the sensory attributes of food products, which is crucial to attracting consumer insight. The texture of cladodes–wheat bread was significantly ($P< 0.05$) affected by the pretreatment method and blending ratio. However, it had not significantly ($P>0.05$) affected by the interaction of the pretreatment method and blending ratios. Nevertheless, composite bread formulated from blanched cladodes flour and a 5% blending ratio had a higher texture score of 6.5, whereas the control exhibited the highest texture score. These variations might be due to the low availability of gluten protein in cladodes flour, increasing the loaf volume of blended bread products. Surprisingly, the texture samples produced from the 20% blending ratio were more accepted by the sensory panellists than the 15% blending ratio which scored (5.53) compared to the 15% blending ratio, which was obtained 5 out of the given hedonic scale.

The aroma of cladodes–wheat bread was significantly ($p < 0.05$) affected by the pretreatment method and blending ratio but had not significantly $P > 0.05$) affected by their interaction. As indicated in Table 6, there was a general decrease in the aroma score with increased cladodes flour proportion. The highest score was 6.3 (liked moderately) for control samples. The lowest scores were for unblanched samples and with cladodes proportion of 20%, which scored 3.

The flavour of cladodes–composite wheat bread was significantly ($P < 0.05$) affected by the blending ratio and had not been significantly ($P>0.05$) affected by the pretreatment method and interaction of blending ratio and pretreatment method. Composite bread from blanched cladodes flour formulated with cladodes flour proportion of 5% resulted in the highest score of 6.16 (moderately liked). A decrease in odour and taste score of cladodes–wheat flour composite bread with an increase in cladodes flour proportion has been reported in earlier studies (Abera et al., 2017; Moreno et al., 2009), which in agreement with the present study's findings.

The overall acceptability scores of cladodes–wheat composite bread is presented in Table 6. Pretreatment methods, blending ratio, and the interaction between the drying method and blending ratio significantly ($P < 0.05$) influenced the overall acceptability. The score ranged from 3.53 to 6.23, which could be associated with neither like nor dislike and like moderately, respectively. However, there was a general decreasing trend in the acceptability score with an increase in the proportion of cladodes flour.

Table 6. The sensory acceptability of bread products as affected by the interactions of pretreatments and Blending Ratios

Code	Colour	Flavour	Taste	Texture	Aroma	Overall acceptability
CB	6.17 ± 1.18^{a}	6.67 ± 0.71^{a}	6.20 ± 1.15^{a}	6.80 ± 0.610^{a}	6.3±1.112a	6.23 ± 0.68^{a}
CU	6 ± 1.29^{a}	6.60 ± 0.62^{a}	5.90 ± 1.27^{ab}	6.33 ± 1.12^{abc}	6.03 ± 1.12^{ab}	6.0 ± 1.05^{ab}
F1B	5.53 ± 1.136^{ab}	6.16 ± 0.83^{a}	5.77 ± 0.68^{ab}	6.50 ± 0.68^{ab}	5.53 ± 1.14^{bcd}	5.83 ± 0.75^{abc}
F1U	5.90 ± 1.15^{ab}	6.17 ± 0.87^{a}	5.60 ± 1.07^{ab}	6.03 ± 0.99^{bcd}	5.57 ± 1.38^{bc}	5.63 ± 0.96^{bcd}

F2B	5.30±1.24^{bc}	5.50±1.14^{b}	5.43±1.073^{bc}	5.76±1.22^{cd}	5.30±1.207^{cd}	5.33±1.18^{cde}
F2U	4.57±1.57^{d}	5.34±1.29^{b}	4.46±1.52^{d}	5.50±1.33^{de}	4.43±1.55^{e}	4.57±1.45^{fg}
F3B	4.80±1.06^{cd}	5.10± 1.09^{bc}	4.83±1.08^{cd}	5.63±1.425^{de}	4.90±1.34^{de}	5.04±1.129^{def}
F3U	4.57±1.69^{d}	5.13±1.22^{bc}	4.30±1.6^{d}	5±1.55^{e}	4.40±1.376^{e}	4.37±1.27^{g}
F4B	4.8±1.32c^{d}	4.77± 1.19^{cd}	4.9±1.19^{cd}	5.53±1.41^{de}	4.53±1.61^{e}	4.94±1.29^{efg}
F4U	3.33±1.53^{e}	4.30±1.64^{d}	3.40±1.47^{e}	4.33± 1.94^{f}	3.33±1.647^{f}	3.53±1.63^{h}
LSD	0.68	0.56	0.63	0.65	0.69	0.59

Values are means ± SD and values in the same column with different superscript letters significantly differed ($P < 0.05$). Note: CB, CU, F1B, F1UB = control (100% wheat flour) with blanched cladodes flour, control (100% wheat flour) with unblanched cladodes flour, 5% Formulation or blending ratio with blanched cladodes flour, 5% formulation or blending ratio with unblanched cladodes flour, respectively. F2B, F2U, F3B, F3U = 10% formulation ratio or blending ratio with Blanched cladodes flour, 10% formulation or blending ratio with unblanched cladodes flour, 15% formulations or blending ratio with blanched cladodes flour and 15% formulations or blending ratio with unblanched cladodes flour, respectively and F4B, F4U, = 20% formulations or blending ratio with blanched cladodes flour, and 20% formulations or blending ratio with unblanched cladodes flour respectively.

Figure 3. Bread product formulated from blanched and unblanched cladodes flour

4. Conclusion

This study aimed to assess the effect of slice thickness, pretreatment, and drying temperature on cladodes flour's functional properties. The results showed that the functional properties such as oil absorption capacity, water absorption capacity, swelling Power and water solubility index of unblanched pretreatment samples values were generally higher than that of blanched or the samples treated by hot water at 95 °C except for bulk density which had higher values under blanched samples. Except for texture, the sensory results revealed that as the blending ratio of cladodes flour increased, the sensory attributes decreased. Significantly, the colour of the bread was close to green as the parameters mentioned above increased, resulting in the decrement of these attributes. Generally, the data scored from the sensory analysis of samples using the seven hedonic scale revealed that the bread product made from a 5% blending ratio and blanched cladodes flour acceptability on the market would be more accepted. It can further be concluded that processing the cladodes flour and using it in the bakery industries is the most important to overcome the problem of food insecurity around the world and also to enrich the nutritional value of wheat flour which was remained on the bran or the aleurone layer of the wheat flour.

Practical applications

Blending this miraculous plant (opuntia ficus-indica) with wheat flour to make bread is a promising development for those seeking healthy and sustainable food options. A recent study revealed that utilizing cladodes flour by using different pretreatment methods is very essential to stabilize the sensory attributes of bread products, particularly the texture of the product. Hence, processing the cladodes flour and using it in the bakery industries is the most important to overcome the problem of food insecurity around the globe and also to enrich the nutritional value of wheat flour and improve and strengthen the sensory characteristics of bread products.

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