Physico-chemical and sensory evaluation of cactus pear (*Opuntia ficus-indica* L. Mill and *Opuntia robusta* Wendl) cladode flour in different baked products

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ABSTRACT

Cactus pear (*Opuntia ficus-indica* and *O. robusta*) cladode flour was used to prepare and evaluate three types of baked products. Data from the physical and chemical analysis were analyzed by analysis of variance (ANOVA). The significance of the overall sensory acceptance measured for each sample was tested by means of ANOVA. After the data was calculated, the results were represented as a spider plot, where a specific spoke denotes a specific attribute. Health bread, containing three different types of seeds and whole wheat flour was prepared. Whole wheat flour was replaced with cactus pear flour in percentages of 2, 4, 6, 8, 10, 12 and 17% replacement. The volume decreased and the texture became more solid and firm. The brown colour of the bread darkened when the percentage replacement of the flour increased, although it was still acceptable to the consumer. Crunchy oats biscuits were manufactured with increasing replacement levels (0, 5, 10, 20 and 50%) of wheat flour with cactus cladode flour from three different cultivars, *Opuntia ficus-indica* ("Skinners Court" and "Morado") as well as *Opuntia robusta* ("Monterrey"). Cultivar had a significant ($p < 0.001, 0.0001$) effect on color, taste and texture, but not on appearance. Increasing inclusion levels of cactus pear flour had a significant ($p < 0.0001$) effect on all the sensory attributes evaluated. The taste that was most liked by the panel was that of the Morado 10% inclusion level sample. Cladode flours were found to affect quality parameters of texture, color and taste of the biscuits. With the increase in the level of cladode flour in the formulation of a popular South African carrot cake, the sensory scores for the organoleptic characteristics of the cakes decreased. The control samples (0% cactus flour) had maximum overall acceptability, whereas cakes containing 75% and 100% cladode flour were found to be unacceptable to the panellists. From the overall acceptability rating, it was concluded that cladodes flour could be incorporated up to 25% level in the formulation of these cakes.

Keywords: *Opuntia* cladode flour, carrot cake, seed bread, crunchy oats biscuits.

INTRODUCTION

Cactus pear is a promising crop with large potential for breeders, agriculturists and food technologists. In future, declining water resources and global desertification may increase the importance of *Opuntia* sps. as an effective food production system, including both fruit and vegetable (Moßhammer *et al.* 2006). The cultivation of cactus pear requires low input and is therefore conducive to a sustainable system that will increase the efficiency and economic viability of the small and medium-sized farms of low-income farmers. Cactus pear is very important in subsistence agriculture in South Africa, where it is used for both fodder and fruit for home consumption (Oelofse *et al.* 2006).

Many food products can be obtained from cactus pear fruit and cladodes, and it is desirable to develop and increase the processing technologies applicable to this crop (Saenz, 1996). Some of the natural ingredients obtained from the cladodes are hydrocolloids that are mixed with oil in baking, as well as fibre (nopal flour) that can be blended with wheat flour for the preparation of baked goods (Saenz, 2000). Flour has recently been used in the baking industry and has potential for manufacturing cookies, pastries, soups and desserts, as well as pelletized fibres. The latter application has become important because it increases consumption of soluble fibre, significantly improving the digestion of people with constipation. Cladodes are an important source of this type of fibre (Saenz, 2013). On the other hand, patients with celiac sprue suffer from distention, diarrhoea and greasy stools. Higher water-binding and emulsification properties of the soluble fibre mucilage in cladode flour will benefit these patients (McQuaid, 1996). Furthermore, the age of the cladodes influences the characteristics of the flour (Saenz, 2013).

The greatest amount of dietary fibre in wheat is in the outer layer or bran, of the wheat grain. When white flour is produced, the bran layer is removed and the dietary fibre content of the flour is greatly reduced. Flour made from whole grains contains about three times as much dietary fibre as white flour (Charley, 1986). There are many different sources of dietary fibres that have been used to replace wheat flour in the preparation of bakery products. These include the polysaccharides cellulose, wheat bran and oat bran in bread making. Potato peel, a by-product from the potato industry, rich in dietary fibre, was used as a source of dietary fibre in bread making. Fibre concentrates from mango fruit has also been used as a bakery product ingredient. Some scientists have also used hazelnut as a source of dietary fibre in bread making. Fibre has an influence on cereals which involves the rheological characteristics of wheat flour dough (Ayadi *et al*. 2009). Since cactus pears are high in dietary fibre, minerals, phenol contents, it shows greater technological potential for water binding capacity and fat absorption. Cladode flours have significant differences to wheat dough properties such as increased tenacity, energy, adhesion, stickiness and hardness of dough and decreased elasticity of dough.

All baked products have almost the same basic ingredients: flour, sweeteners, salt, leavening agents, eggs, fat (butter, margarine, shortening, or oil), and liquid such as milk and water. Substitutions can be made and varying the proportions of ingredients will alter the flavour and texture of the products. The method of mixing, the major flavouring, and the ratio of liquid in the batter will determine the type of bread or cake (Charley, 1986; Lauterbach and Albrecht, 1994).

Flour will provide a baked product its structure. Wheat flour contains proteins that interact with each other when mixed with water to form gluten. This elastic gluten framework will stretch to contain the expanding leavening gases during rising (Charley, 1986). The end products are determined by the wheat's characteristics, especially protein and gluten content. It is the protein content that affects the strength of the dough (Lauterbach and Albrecht, 1994). The harder the wheat, the higher the protein content in the flour. Soft, low protein wheat is used in cakes, pastries, cookies, crackers and Oriental noodles. Hard, high protein wheat is used in breads and quick breads. Cake flour, used in carrot cake, is wheat flour that has 7.5% protein. The lower gluten content causes products to have a tender, more crumbly texture that is desirable in cake (Charley, 1986). In yeast bread, a strong gluten framework is desirable, but a high protein flour will cause a tough texture in cakes, quick breads and pastries (Lauterbach and Albrecht, 1994). Bread flour is a hard wheat flour with 12% protein and is used for yeast raised bread. All purpose flour is blended to have a protein content of 10.5%. Whole wheat flour contains germ, bran as well as endosperm. Bran particles cut through gluten during mixing and kneading to result in a smaller, heavier loaf. Other non-wheat grains can be used in baked goods. These are rich in protein, but cannot develop gluten (Lauterbach and Albrecht, 1994).

Wheat flour also contains complex carbohydrates. All types of wheat flour derive at least 80% of their calories from carbohydrates. The percentage of calories from protein ranges from 9 to 15% (depending on the flour type). Calories from fat are never more than 5%.

Fats (solid shortening, margarine, butter or oil) contribute to tenderness, moistness, as well as a smooth mouth feel in baking of baked goods. Fats enhance the flavors of other ingredients as well as contributing to its own flavor. Reducing the amount of fat in a products such as muffins, results in a tougher product because of gluten developing more freely (Lauterbach and Albrecht, 1994). If oil is used in cake mixtures instead of solid fats the texture of the cake will be much heavier, just as it is in carrot cake (Charley, 1986). Oil will tenderize a product and is therefore desirable in quick-breads. It reduces dryness and enhances flavor (Charley, 1986). Another tenderizing agent is sugar that can be added or increased. Fat in yeast dough will help the gluten to stretch, creating a loaf with greater volume (American Home Economics Association, 1980). Fats' tenderizing ability comes from dispersing of the fat particles. It allows them to coat the starch molecules. This coating prevents too much gluten from forming, and preventing the dough from getting tough. In quick bread and cake, oil is used. Stirring will prevent gluten formation and the structure will be denser (Charley, 1986; Lauterbach and Albrecht, 1994).

Aim

The aim of this research was to investigate whether or not the *Opuntia* cladode flour could be used in bakery products by partially substituting wheat flour: which cactus species and cultivars should be used? What baked products are suitable? At what levels should inclusions be made?

MATERIALS AND METHODS

Cactus pear cladode flour and baked products

Mature cladodes (two years old) from *Opuntia ficus-indica* and *Opuntia robusta* were harvested from an experimental orchard outside Bloemfontein (GPS coordinates 29°10'53"

S, 25°58’38” E), South Africa. The cladodes were washed in chlorinated water, mechanically cut into strips by a rotating blade cutter and sun dried (7-10 days). The dried cladode strips were milled into fine flour, vacuum packed and frozen until use.

The above-mentioned two spineless Burbank cactus pear species are the most frequently planted and used in South Africa. *Opuntia robusta* (cultivar “Monterrey”) is a popular animal feed cultivar with round blue-ish cladodes and dark purple fruit. Two cultivars of *Opuntia ficus-indica*, called “Morado” and “Skinners Court”, were included to represent the two dominant growth types of cactus pears. These are popular commonly found green/white fruit cultivars, with Morado growing into relatively low, dense bushes with round cladodes and Skinners Court, having elongated candelabrum cladodes (Fouche, 2015; personal communication).

Three different types of baked products were prepared, carrot cake, seed bread and crunchy oats biscuits. Flour from *O. robusta* (cultivar: “Monterrey”) cladodes was used to partially replace wheat flour in a popular South African cake. Carrot cake is a quick bread because, unlike traditional bread dough, there is no yeast used in the recipe and no need to wait hours for the bread dough to rise. In a quick bread, the leavening agent is usually baking powder. In the method of preparation, all the wet ingredients are mixed together, while all the dry ingredients are separately mixed, where after the two mixtures are combined. The batter has a denser consistency than traditional cake batter, along with a coarser crumb (Pienaar, 2007). The grated carrot in the batter softens during the baking process and the cake usually has a soft, dense texture, while the carrots enhance the flavor, texture, and appearance of the cake (Charley, 1986).

The seed bread consists of yeast and whole wheat flour, and a variety of seeds, including lin, sesame and sunflower seeds and is prepared by the straight dough method (Foods and Cookery, 1984). Whole wheat flour was replaced with *Opuntia robusta* (cultivar “Monterrey”) flour.

Flour from cladodes of *Opuntia ficus-indica (*cultivars “Morado” and “Skinners Court”) and *Opuntia robusta* (cultivar “Monterrey”) was used to prepare the crunchy oats biscuits. These biscuits are made from firm dough and are shaped by hand and pressed flat (Foods and Cookery, 1984).

These different baked products represented a variety of different ingredients, mixing techniques and batter/dough formation, which resulted in distinct textures and flavours in the final baked products. Since it is known from literature that the incorporation of cactus flour in baked products has an influence on colour and texture, it was decided to evaluate the effect of ingredients such as carrots, seeds and oats on those organoleptic parameters. Furthermore, it was also investigated if these ingredients could mask the effect of cladode flour on colour, texture and acceptability of the final products.

Flour replacement

Carrot cake: Five different formulations were used to evaluate the effectiveness of the cladode flour to replace wheat (cake) flour, namely the control containing 0% cactus flour, 25%, 50%, 75% and 100% of cladode flour. The higher concentrations of up to 100% were included, because it is acceptable nowadays to use gluten-free flours, such as almond flour, to bake cakes which are characterized by lower volumes (Nataniel, 2002). Celiac sprue sufferers will improve on a gluten-free diet, since it is also known as gluten enteropathy. Gluten causes an inflammatory response that results in mucosal inflammation and destruction (McQuaid, 1996)

Seven health breads were prepared from blends containing 0, 2, 4, 6, 8 10 and 17% of cladode flour. The replacement percentages chosen for this bread were much lower than for the other products, because the volume of the bread was already lower, because of all the seeds and fibre from the whole wheat flour. Furthermore, it is suggested that gluten-free flour should not be added at concentrations higher than 8%, as it will seriously compromise the volume and texture of the final product (Bennion and Scheule, 2005).

Five different formulations were used for the crunchy oats biscuits, containing 0, 5, 10, 20 and 50% cladode flour. These percentages were chosen because it was reported by Saenz *et al.* (2002) that cactus flour inclusion levels of up to 25% were acceptable in preparation of oatmeal cookies enriched with cactus flour.

Physical Analysis

Water activity (a_w)

Water activity of the ground baked samples was measured with a Novasina thermoconstanter set at 22°C (James, 1995). Water activity is the ratio of the water vapour pressure in any kind of food system to the water vapour pressure of pure water.

a_w = p product/p water.

Volume of bread and cake

To measure the volumes of the products a displacement method was used. The volume of the baked product is found by subtracting the volume of low density seeds, e.g. linseeds, held in a container with and without the product. The volume of seeds required to fill the container was measured. Thereafter, a baked sample was put into the container and covered with seeds. The second seed volume was measured and subtracted from the first reading (without the baked products) (Campbell *et al.* 1980).

Texture of the baked samples

The textures of the samples were determined using a Stanhope-Seta penetrometer with different adjusters (cone, flat and needle). The depth that the needle was able to penetrate the sample was measured in units of tenths of 1 mm (10ths/mm). When using the penetrometer, the action of the cone and needle is similar to the action of the teeth biting into the cake (Campbell *et al*. 1980).

Chemical Analysis

Protein content

Nitrogen and protein content of the samples was measured by means of thermal combustion. A Leco Protein/Nitrogen FP-528 combustor was used. Approximately 0.2 g dry matter (DM) of each sample was weighed accurately in a tiny foil cup. Each foil cup and sample was then inserted in a Leco Nitrogen analyser (Leco Corporation, 2001). The nitrogen (N) content was determined automatically by combustion in oxygen. A factor of 6.25 was used in the calculations to convert the N content of the samples to protein content.

Fibre content

The fibre content was determined using the acid fibre detergent process (Goering *et al*. 1970). A Fibretech 1020 hot extraction system was used. In the process cell components are removed and highly digestible plant constituents like proteins, soluble carbohydrates, fats and soluble mineral are washed away. The acid detergent will be left with cellulose, lignin, cutin, silice and ash.

Sensory analysis

A consumer panel of 55 members, comprising of staff and students, was used to evaluate the baked samples and consisted of male and female consumers, between the ages of 20 to 60 years. Apart from acceptability, degree of liking of aroma, degree of liking of taste, degree of liking of color and degree of liking of texture were also evaluated for the samples. All samples were served and evaluated according to the sensory principles and methods described in the ASTM Manual on Sensory Evaluation (ASTM Manual Series: MNL 13, 1992).

Bread, cake and biscuit cubes of 1x1x1 cm were served on white polystyrene trays. Before starting and in between sampling, panelists cleansed their palettes with a sip of mineral water (Aquartz still mineral water, Clover SA (Pty) Ltd.). Respondents were asked to respond to the question “how much do you like or dislike the sample?” on a nine-point hedonic scale (Stone and Sidel, 2004). All samples were coded with randomized, three-digit codes and rotated to prevent bias. Tasting were done in individual booths and under red lights as to prevent bias, at the Sensory Laboratory of the Food Science Division, Department of Microbial, Biochemical and Food Biotechnology, University of the Free State.

Statistical analysis

All the data were collected in spread sheets using Microsoft Excel 2007 and all the statistical analyses were done using XLSTAT 2007 (NCSS, 2007). The significance of the overall acceptance measured for each sample was tested by means of ANOVA. The different samples were used as the main effects at a significance level of $p<0.001$. If the main effect was significant, Fisher’s LSD-test was applied to determine the direction of the differences between mean values (Heymann, 1995).

After the data was calculated, the results were represented as a spider plot, where a specific spoke denotes a specific attribute. The distances of attribute mean from the centre of the plot along each spoke directly corresponds to attribute intensity. The plot provides a visual presentation of product similarities and differences. For each attribute, the relative intensity increases as it moves further away from the centre point (Heymann, 1995).

RESULTS AND DISCUSSION

Carrot cake

The appearance (visible color and volume) and texture of the carrot cake was influenced by the incorporation of cactus flour (Figures 1a and 1b). This was particularly visible on the crust, with an increase in darkness, as well as cracks appearing on the surface. The volume of the cakes also decreased and became more compact with an increase in concentration of the cactus flour. No peaks and tunnels formed with increased concentration. Surface breakdown in baked wheat products with increased cactus pear flour inclusion was reported by Ayadi *et al.* (2009). The fortification with cactus flour increased water holding capacity (WHC) and increased the tenacity, while decreasing the elasticity, therefore causing an increase in hardness and stickiness. These authors also reported increased browning, because of the Maillard reaction, as well as caramelization. Samia El-Safy (2013) reported increased resistance to extension and decreased extensibility in sponge cake.

Figure 1a. Whole carrot cakes with increasing cactus flour levels from 0 (left), 25, 50, 75 to 100% (right).

Figure 1b. Sliced cakes indicating cactus flour levels from 0 (left), 25, 50, 75 to 100% (right).

Physical and chemical analysis of carrot cake

There was a significant ($p < 0.001$) difference between a_w of the control and 25%, and that of the other samples (Table 1). Water activity of foods is a very important aspect of food preservation. The growth of various microorganisms stops at a given level of a_w. Water activity also affects other aspects, such as quality and organoleptic properties. The lowest limit for growth in foods is ~ a_w 0.6. In the narrow range between a_w 0.6 - 1 a large number of microorganisms can grow which are potentially dangerous to humans. All the samples had the required a_w to inhibit the growth of microorganisms and ensure a longer shelf life. Cake with no or low contents of cactus flour had significantly lower a_w values than those containing 50, 75 and 100%. Ayadi *et al.* (2009) reported an increased WHC in wheat products enriched with cactus flour, while Samia El-Safy (2013) found increased water adsorption and increased moisture content, because of the high fibre content of the cladodes.

Table 1. Analysis of variance (ANOVA) of physical and chemical data of carrot cakes with different % of cactus flour replacement.

Sample	**a_w**	**Volume (ml)**	**Firm-cone (10thsm/m)**	**Firm-flat (10thsm/m)**	**Fibre (%)**	**Protein (%)**
0%	$0.46±0.01^a$	$346.67±2.89^c$	$129.00±0.40^c$	$12.50±0.50^b$	30.84	11.59
25%	$0.47±0.01^a$	$323.33±2.89^b$	$118.00±3.00^b$	$11.00±0.07^a$	30.25	8.74
50%	$0.48±0.01^b$	$343.33±2.89^c$	$116.00±1.00^b$	$10.53±0.06^a$	30.68	8.01
75%	$0.48±0.01^b$	$340.67±1.15^c$	$113.33±0.58^b$	$10.57±0.06^a$	29.58	6.93
100%	$0.48±0.01^b$	$311.67±2.89^a$	$75.00±4.00^a$	$10.40±0.07^a$	30.31	6.56
P value	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$		

Firm-cone = firmness with cone adjuster, Firm-flat = firmness with flat adjuster
Means with different superscripts in the same row differ significantly.

The volume of the control cake was on average 346 ml and decreased to 311 ml at 100% replacement. From the appearance it was clear that the cactus flour retained all the liquid components of the cake ingredients, therefore making the texture very dense (as was seen with a_w). The addition of cladode flour increased dough tenacity and decreased its elasticity. This might be due to the strong WHC capacity and less gluten formation (Ayadi *et al.* 2009).

The texture, measured by the penetrometer, showed that the texture became stiff and less elastic with increased cladode flour replacement. There was a significant ($p<0.001$) difference in the textural characteristics of the control and the cactus flour inclusion samples. These results might be either due to the dilution of gluten proteins or because of interactions between polysaccharides from the cladodes and proteins from wheat flour. This rheological and textural change in texture properties may also be due to the interaction between fibrous materials and gluten, which affects the texture mixing properties of the cladode flour (Ayadi *et al.* 2009).

During preliminary chemical analysis, it was observed that the fibre content remained more or less the same in all the samples. However, it was anticipated that there would be an increase in fibre content in the cactus flour cakes. Fortification of wheat flour by cladode powder as a source of dietary fibre leads to a change in texture properties. Cladodes, like any other fibre source, increase water absorption capacity of the flours and consequently the texture properties. Cladode flours were found to affect quality parameters of texture and volume of cakes significantly ($p<0.001$). Baking tests showed that cladode incorporation causes a great change on cake texture aspects and quality, especially for levels more than 10% (Ayadi *et al*. 2009). Also, increased fibre contents in sponge cake were reported by Samia El-Safy (2013).

Regarding the protein content, there is a numerical difference between the wheat flour control cake at 11.6% and the 100% cactus flour cake at 6.6%. The protein content of flour affects the strength of dough (Charley, 1986; Lauterbach and Albrecht, 1994). Both wheat and cactus cladodes are good sources of proteins. However, the type of protein (e.g. gluten) will affect the strength and therefore the texture of the dough. Decreased protein content (from 7.9% to 6.1%) was observed in sponge cake with increasing cactus flour inclusion levels (Samia El-Safy, 2013).

Sensory analysis

Regarding the overall acceptability, there were significant (p<0.001) differences among the samples, except between the 75% and 100% cakes (Table 2). The control sample scored a value of 6.82 ('like slightly') from where the scores decreased to 2.48 ('dislike very much') for the 100% inclusion sample.

Table 2: Analysis of variance (ANOVA) of consumer panel data for the carrot cakes.

Treatment	Overall acceptability	Taste	Texture	Appearance
0% replacement	6.82 ± 1.32^d	6.82 ± 1.42^d	6.94 ± 1.32^d	6.46 ± 1.72^c
25% replacement	5.75 ± 1.54^c	5.70 ± 1.66^c	5.98 ± 1.44^c	6.10 ± 1.50^c
50% replacement	3.94 ± 1.74^b	3.68 ± 1.80^b	4.70 ± 1.69^b	5.14 ± 1.83^b
75% replacement	3.06 ± 1.94^a	2.84 ± 1.83^a	3.62 ± 1.78^b	4.10 ± 1.89^a
100% replacement	2.48 ± 1.55^a	2.30 ± 1.53^a	3.22 ± 1.82^b	3.54 ± 1.82^a
Significance Level	p < 0.001	p < 0.001	p < 0.001	p < 0.001

Means with different superscripts in the same column differ significantly.

As was observed with the overall acceptability, the liking of the taste scores followed the same trend. The samples differed significantly (p<0.001) from each other, with the 75% and 100% having no difference between them. The score of the control cake was 6.82 and decreased gradually to a low score of 2.30 for the 100% cake. On the hedonic scale used, a value of 2 implicates an extremely dislike value. Samia El-Safy (2013) reported that the taste decreased and that the appearance was influenced by cactus flour inclusion in sponge cakes.

Regarding the texture of the samples, there were differences (p<0.001) between the control, 25% and the other three replacement samples. The incorporation of 50% and more cactus flour had a significant (p<0.001) influence on texture, as was seen with the physical tests (Table 1). Ayadi *et al.* (2009) observed an increase in hardness, stiffness and stickiness in products with increased cactus flour inclusions.

The appearance of the cakes decreased with the increased incorporation of cactus flour. The control and 25% samples did not differ, but were different (p<0.001) from the other higher inclusion samples. Increased darkness and reduced appearance in sponge cake was reported by Samia El-Safy (2013), while Ayadi *et al.* (2009) observed an increase in darkness and greenness.

With the increase in the level of cladode flour in the formulation of carrot cake, the sensory scores for organoleptic characteristics of the cakes decreased. The control samples had maximum overall acceptability, whereas cakes containing 75% and 100% cladode flour were found to be unacceptable to the panellists. The overall acceptability score for the control was 6.82 on a 9-point hedonic scale. Cakes made from blends containing 25% cladode flour differed significantly from the control, however, from the overall acceptability rating (5.74), it was concluded that cladode flour could be incorporated up to 25% level in the formulation of carrot cakes.

Health seed bread

Increasing contents of cactus flour caused the volume and texture of the seed bread to change noticeable (Figure 2). The volume decreased and the texture became more solid and firm. Ayadi *et al.* (2009) also reported an increase in density in wheat baked products with cactus flour inclusions.

Figure 2: The seven cladode flour substitution seed bread samples, from the control, 2, 4, 6, 8, 10 and 17% inclusion level.

Table 3: Analysis of variance (ANOVA) of physical data for seed bread.

Volumes	Volume (linseeds) (ml)	Penetrometer Needle (10ths m/m)	Water Activity (25°C)	Penetrometer-triangle disk (10ths m/m)
Control	263.33 ± 7.64^{ab}	69.48 ± 36.79^{ab}	88.53 ± 0.67^{b}	81.08 ± 16.41^{ab}
2%	260.00 ± 5.00^{ab}	60.64 ± 7.02^{ab}	85.53 ± 1.15^{a}	69.42 ± 12.55^{ab}
4%	256.33 ± 3.21^{ab}	71.18 ± 40.03^{ab}	87.70 ± 1.11^{b}	94.50 ± 3.04^{b}
6%	259.00 ± 1.73^{ab}	67.88 ± 13.02^{ab}	86.87 ± 0.40^{ab}	83.32 ± 4.61^{ab}
8%	253.33 ± 24.66^{a}	112.91 ± 6.86^{b}	86.47 ± 0.40^{ab}	85.17 ± 17.08^{ab}
10%	270.67 ± 7.51^{ab}	50.88 ± 4.87^{a}	86.63 ± 1.17^{abc}	71.92 ± 16.39^{ab}
17%	278.33 ± 5.77^{b}	66.20 ± 11.53^{ab}	86.70 ± 1.70^{ab}	63.92 ± 4.11^{a}
P value	$p<0.1$ (p = 0.087)	$p<0.1$ (p = 0.051)	$p<0.001$	$p<0.05$

Means with different superscripts in the same column differ significantly.

Regarding the volume measurements (ml linseeds), only the 8 and 17% flour differed significantly ($p<0.1$) from each other (253.33 and 278.33) (Table 3). Ayadi *et al.* (2009) observed a decrease in elasticity and increase in resistance to extension of dough with cactus flour. The values for the penetrometer needle showed that there were differences ($p<0.1$) between the 8% (112.91) and 10% (50.88) samples. The penetrometer triangle disk (cone) measurements showed differences ($p<0.05$) between the 4% (94.50) and 17% (63.92) samples.

The higher the inclusion rate of cactus cladode flour, the higher the resistance against the penetrometer attachment, therefore an observed increase in firmness. This is in correspondence with the results of Ayadi *et al.* (2009), who reported an increase in dough hardness. With the penetrometer results (both needle and cone) there was a trend for the firmness to increase in increasing substitution levels. The differences observed between the techniques (needle and cone) may be explained by the nature of the attachment, as well as the presence of seeds in the dough, which could influence the penetration of the needle into the bread. Moreno-Alvarez *et al.* (2009) reported increased water absorption and decreased dough stability in bread with cactus flour inclusion, while Ayadi *et al.* (2009) noted an increase in stickiness, hardness and density.

The most important parameter to indicate the suitability of flour replacement in this type of product is a_w. Seed bread, like the one used in this study, should be an intermediate moisture food (IMF), with a_w of 0.65-0.35, which will ensure a stable product which can be kept at room temperature. The lowest a_w was measured for the 2% sample (0.855), which differed ($p<0.001$) from the control sample (0.885) and 4% (0.877) sample. Water activity decreases (although not statistically) with inclusion of cactus cladode flour. Increased water absorption and a high water content in sponge cake was reported by Samia El-Safy (2013), while Ayadi *et al.* (2009) reported more water interactions, therefore less free water for reactions and therefore a lower a_w.

Regarding the sensory analysis (Table 4) it is evident that there were no differences for any of the attributes tested. None of the scores was above 6.4, representing 'like slightly' on the nine-point hedonic scale. The lowest score was 5.96, representing 'neither like nor dislike'. Aroma had the highest numerical values amongst the attributes tested, for all the samples, except for the 17% sample, which had a higher score for taste (6.36) and overall acceptability (6.38). Mouthfeel had the lowest score for the 10% sample (5.96= 'neither like nor dislike'). The presence of seeds may mask the effect on the sensory parameters. In contrast to the results of the present study, Moreno-Alvarez *et al.* (2009) reported that the inclusion of cactus flour in bread affected the sensory properties.

Not very high inclusion levels were tested. Moreno-Alvarez *et al.* (2009) concluded to an incorporation level of 5-10%. In the present study, up to 17% was still acceptable. Moreno-Alvarez *et al.* (2009) concluded that cactus flour is a weak flour and that it should be used in cookies and biscuits. For a bread, flour needs to have a protein content of >13%. These authors also reported that replacement of wheat flour with cactus flour affected the sensory analysis. However, in the present study it was found that the cactus flour only influenced the physical analysis.

Table 4: Analysis of variance (ANOVA) of consumer panel data for seed bread.

Sample	Aroma	Taste	Texture	Overall acceptability
Control	6.40 ± 1.32	6.40 ± 1.58	6.28 ± 1.55	6.34 ± 1.52
10% Cladode flour	6.34 ±1.27	5.98 ± 1.72	5.96 ± 1.54	5.98 ± 1.63
17% Cladode flour	6.28 ±1.11	6.36 ± 1.32	6.16 ± 1.33	6.38 ± 1.23
Significance Level	NS (p = 0.8660)	NS (p = 0.4050)	NS (p = 0.3590)	NS (p = 0.4140)

NS = Not significant

Crunchy oats biscuits

Sensory analysis

The taste that was most liked by the panel, was that of the Morado 10% inclusion level sample, which scored 7.12 (Table 5), associated with 'like moderately' on the hedonic scale. The lowest score (3.90) for liking of taste was for the Skinners Court sample (Table 5), with the inclusion level of 50%, representing 'dislike moderately' on the hedonic scale. For liking of the texture attribute, the highest value was given to the Morado inclusion level 10% sample, which also had the highest score for taste. Saenz (2013) suggested increased contents of oats, cinnamon and other flavorings to mask the flavor of the cladode flour.

Table 5: ANOVA on the sensory effect of cultivar and inclusion level on the color, taste, texture and appearance for the crunchy biscuit variants

Cultivar	Colour	Taste	Texture	Appearance
Control	7.34 ± 1.36^{e}	6.47 ± 1.58^{bc}	6.17 ± 1.93^{de}	7.13 ± 1.41^{f}
Morado 5%	6.94 ± 1.24^{de}	6.36 ± 1.34^{bc}	6.14 ± 1.60^{cde}	6.70 ± 1.28^{def}
Skinners Court 5%	7.16 ± 1.36^{de}	6.48 ± 1.50^{bc}	5.14 ± 2.21^{bcd}	6.78 ± 1.37^{ef}
Monterrey 5%	6.94 ± 1.42^{de}	6.50 ± 1.36^{bc}	5.50 ± 2.23^{bcde}	6.70 ± 1.57^{def}
Morado 10%	6.68 ± 1.53^{cde}	7.12 ± 1.65^{c}	6.62 ± 1.82^{e}	6.78 ± 1.59^{ef}
Skinners Court 10%	6.66 ± 1.26^{cde}	6.00 ± 1.62^{b}	5.56 ± 2.11^{bcde}	6.20 ± 1.48^{de}
Monterrey 10%	6.70 ± 1.25^{cde}	6.20 ± 1.46^{bc}	4.92 ± 2.21^{bc}	6.40 ± 1.53^{def}
Morado 20%	5.72 ± 1.77^{bc}	6.38 ± 1.55^{bc}	6.24 ± 1.61^{de}	5.72 ± 1.77^{cd}
Skinners Court 20%	6.18 ± 1.40^{cd}	5.62 ± 1.55^{b}	5.48 ± 1.82^{bcde}	6.08 ± 1.54^{de}
Monterrey 20%	6.46 ± 1.30^{cd}	5.86 ± 1.26^{b}	5.20 ± 1.83^{bcd}	6.08 ± 1.64^{de}
Morado 50%	3.86 ± 2.08^{a}	4.44 ± 1.89^{a}	4.86 ± 1.83^{b}	4.04 ± 1.76^{ab}
Skinners Court 50%	3.90 ± 1.57^{a}	3.90 ± 1.84^{a}	3.56 ± 1.93^{a}	3.78 ± 1.72^{a}
Monterrey 50%	5.14 ± 1.80^{b}	4.24 ± 1.85^{a}	4.32 ± 1.78^{ab}	4.84 ± 1.80^{bc}
Significance Level	$p<0.001$	$p<0.001$	$p<0.001$	$p<0.001$

Means with different superscripts in the same column differ significantly.

Differences ($p<0.001$) in liking of texture did occur, again mainly for the 50% inclusion level of all cultivars, which was liked less than the control, 5, 10 and 20% inclusion levels. Only the Monterey cultivar showed differences ($p<0.001$) for the liking of the texture attribute, namely between the control and the 10 and 50% inclusion levels. All the other inclusion levels showed no differences for liking of texture. The panel gave the lowest score for liking of the texture to the 50% Skinners Court inclusion level sample, namely 3.56, corresponding to 'dislike moderately' on the hedonic scale. Ayadi *et al.* (2009) also reported increased hardness.

The liking of the appearance that scored the highest value was the control sample, with a value of 7.13, corresponding to 'like moderately' on the hedonic scale (Table 5). A decrease in the liking for the appearance of all the 50% inclusion level samples was observed, compared to the control, 5, 10 and 20% inclusion levels. All the 20% inclusion level samples were also lower in 'liking' values, than the respective cultivar control samples. The sample with the lowest score (3.78) was the 50% inclusion level Skinners Court sample and it was evaluated as being 'disliked moderately' on the hedonic scale (Table 5).

The highest score for color was awarded to the control sample (7.34), representing 'like moderately' on the hedonic scale (Table 5). Liking of the color of the control sample received the highest scores from the consumer panel. It seemed as if the color of the Monterrey and Skinners Court samples received higher values for all inclusion levels compared to the Morado inclusion biscuits. The highest score for the inclusion samples obtained was for Skinners Court 5%, while the lowest score was for Morado 50%. Monterrey 50% received the highest score for the 50% inclusion levels. A general decrease in color acceptance with increasing inclusion levels was observed. Samia El-Safy (2013), as well as Ayadi *et al.* (2009), reported a decreased acceptability in crumb color. Saenz *et al.* (2002) observed that the external color of oatmeal cookies with cactus flour was not influenced by the green cactus pear flour.

From the spider plot (Figure 3) it was clear that the Skinners Court 50% inclusion level sample scored the lowest values for appearance, taste and texture. These were also noted in the physical and chemical analysis. It can also be noted that the highest values for texture and taste were awarded to the 10% inclusion level in Morado sample, while the highest score for appearance and color belonged to the control sample.

In an attempt to explain the sensory results, preliminary physical and chemical analyses were performed. Although not statistically analyzed, important observations were made in relation to the sensory results. The a_w of the control biscuit increased from 0.30 to 0.32 at 50% replacement level, with Skinners Court having the highest values in the 10 and 50% samples. The crunchy biscuit with cactus flour replacement had the required a_w to inhibit microorganisms and ensure a longer shelf life. Samia El-Safy (2013) reported increased water binding in sponge cakes. Saenz *et al.* (2002) reported a_w for oatmeal cookies, enriched with cactus flour, ranging between 0.353 and 0.453 in 15, 20 and 25% enrichment levels, which are in accordance with reported values for similar products.

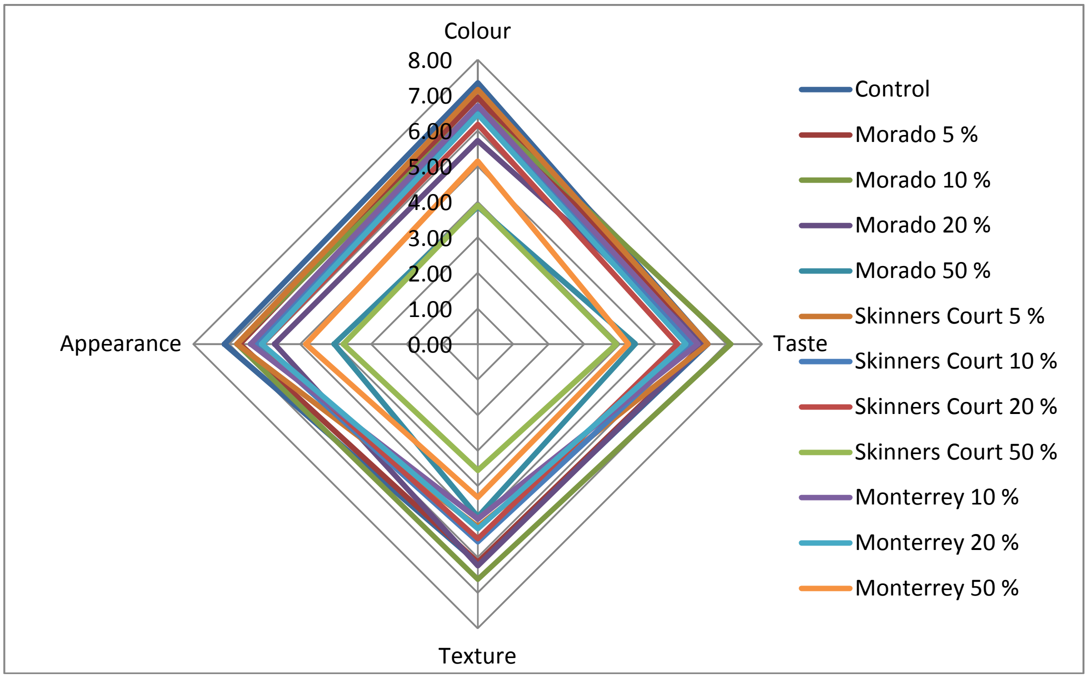

Figure 3: Spider plot for the sensory data for the variants of crunchy biscuits.

The texture measured with the needle attachment showed a general decrease in values from 94 to 91.33. The replacement of wheat flour with cladode flour made the texture more compact and a greater force was required to break the biscuits than that applied to break the control. The hardness of the biscuits was also observed by the sensory panel. The texture was more compact, with especially the replacement of Skinners Court cladode flour. It was observed that the Morado and Monterrey samples showed the same trend and had almost the same values, but there were observed differences in texture between the Skinners Court control and the other four replacement samples (Table 6).

The incorporation of the cladode flour had an influence on the texture as was seen in Table 6. These results might be either due to the dilution of gluten proteins or because of interactions between polysaccharides from the cladodes and proteins from wheat flour. This rheological and textural change in texture properties may also be due to the interaction between fibrous materials and gluten, which affects the texture mixing properties of the cladode flour (Ayadi *et al*. 2009). These authors reported differences between spiny and spineless cactus pear cladode flours. The hardness increased, density increased and surface breakdown was observed. The differences in the results from the present study could be ascribed to the use of flour from different cactus pear species. Saenz *et al.* (2002) observed that oatmeal cookies with added cactus flour required a greater force to break the cookies than that applied to break the control. Furthermore, added flour does not produce abnormal cookie formation. The cookies with added cactus flour presented a lower expansion ratio than the control with a smaller diameter and greater height. This could be attributed to the water absorption capacity of this flour and the lower gluten content of the flour blend.

Table 6: Preliminary analysis of physical and chemical data (mean values) for crunchy oats biscuits

Sample Replacement	Control (0%)	5%	10%	20%	50%
Water activity:					
Morado	0.30	0.30	0.30	0.31	0.31
Monterrey	0.30	0.30	0.30	0.31	0.32
Skinners Court	0.30	0.30	0.31	0.31	0.32
Average	0.30	0.30	0.30	0.31	0.32
Texture (10thsm/m):					
Morado	94.00	94.00	94.00	94.00	94.00
Monterrey	94.00	94.00	94.00	94.00	94.00
Skinners Court	94.00	53.00	65.00	64.00	86.00
Average	94.00	80.33	84.33	84.00	91.33
Fibre (%):					
Morado	13.91	29.67	29.80	29.31	29.77
Monterrey	12.30	29.76	29.63	29.80	29.55
Skinners Court	13.53	30.30	30.03	30.26	30.46
Average	13.25	29.91	29.82	29.79	29.93
Protein (%):					
Morado	9.67	8.60	9.14	8.62	8.74
Monterrey	10.64	8.89	8.88	9.16	8.69
Skinners Court	12.64	8.99	9.30	8.78	8.40
Average	10.98	8.83	9.11	8.85	8.61

The fibre content of the control biscuits were much lower (more than 50% less) compared to the cactus inclusion samples (Table 6). These values remained more or less the same in all the cactus flour inclusion samples. Skinners Court showed a trend to have higher fibre contents. It was, however, anticipated that the fibre content in the cactus pear flour biscuits would increase. Fortification of wheat flour by cladode flour, as a source of dietary fibre, leads to a change in texture properties (Saenz *et al.* 2002). Cladodes, like any other fibre source, increase water absorption capacity of the flours and consequently the texture properties. Cladode flours were found to affect the quality parameter of texture of the biscuits. This was also seen with the penetrometer results for Skinners Court. The fibre content also remained stable in the carrot cake (Table 1). Saenz *et al.* (2002) reported higher total dietary fibre content in all the treatments than in the control oatmeal cookie. There was an increase in both soluble and insoluble dietary fibre and the total dietary fibre content was proportional to the cactus pear flour addition.

Regarding the protein content (Table 6), there was a noticeable difference between the wheat flour in the control samples and the cladode flour samples. As the cactus flour inclusion levels increased, the protein content decreased. The protein content of flour affects the strength of dough and therefore also the texture. This was also seen in the carrot cake and sponge cake (as reported by Samia El-Safy, 2013). Saenz *et al.* (2002) also noted decreased protein content in oatmeal cookies with increased cactus flour inclusions.

CONCLUSIONS

The health bread volume decreases and the texture became more solid and firm. The brown color of the bread also intensified and darkened when the percentage replacement of the flour increased, although it was still acceptable for the consumer. Increasing inclusion levels of the cactus cladode flour in oats biscuits had a significant effect on all the sensory attributes evaluated. The taste that was most liked by the panel, was that of the Morado 10% inclusion level sample. The sensory scores for the organoleptic characteristics of a popular South African carrot cake decreased. From the overall acceptability rating, it was concluded that cladode flour could be incorporated up to 25% level in the formulation of cakes.

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REFERENCES

American Home Economics Association. 1980. Handbook of Food Preparation. 8th Edition.

ASTM Manual Series: MNL 13, 1992. Manual on Descriptive Analysis Testing for Sensory Evaluation (R.C. Hootman ed.) Philadelphia: Library in Congress Cataloging-in-Publication Data.

Ayadi, M.A., Abdelmaksoud, W., Ennouri, M., Attia, H. 2009. Cladodes from *Opuntia ficus-indica* as a source of dietary fibre: Effect on dough characteristics and cake making. Journal of Industrial Crops and Products 30, 40–47.

Bennion, M., Scheule, B. 2005. Introductory foods. (13th ed.). New Jersey: Pearson Prentice Hall.

Campbell, A. M, Penfield, M. P., Griswold, R. M., 1980. The experimental study of food. Constable London. Houghton Mifflin Company.

Charley, H. 1986. Food Science. 2nd edition. New York: Macmillan Publishing Company.

Feugang, J.M., Konarski, P., Zou, D., Stintzing, F.C., Zou, C. 2009. Nutritional and medicinal use of cactus pear (*Opuntia* spp). Cladodes and fruits. Frontiers in Bioscience 11, 2574-2589.

Foods and Cookery 1984. Revised Metricated Edition. Department of Education and Culture Administration: House of Assembly, Pretoria, Government Printer.

Goering, H.K., Van Soest, P.J. 1970. Forage fibre analyses (apparatus, reagents, procedures, and some application). USDA Handbook 379, U.S. Gov. Print. Office, Washington, DC.

Heymann, H. 1995. Introductory Sensory Analysis Workshop. The Sensory Analysis and Human Nutrition Unit. ARC. Irene, South Africa.

IFT, 1974. Hohenheim University, Institute of Food Technology.

James, C.S. 1995. Analytical Chemistry of foods.

Lauterbach, S., Albrecht, J.A. 1994. NF 94-186. Functions of Baking Ingredients. Historical Materials from University of Nebraska-Lincoln Extension. Paper 411.

Leco, 2001. FP-528 Protein/Nitrogen Determinator. FP-528 Instruction Manual, version 1.2. Leco Corporation.

McQuaid, K.R. 1996. Current medical diagnosis and treatment. International Edition. 35th edition. (L.M. Tierney Jr., S.J. McPhee, M.A. Papadakis, Eds.) A Lange medical book. Appleton and Lange, USA. Prentice-Hall International Inc.

Moreno-Álvarez, M.J., Hernández, R., Belén-Camacho, D.R., Medina-Martínez, C.A., Ojeda-Escalona, C.E., García-Pantaleón, D.M. 2009. Making of bakery products using composite flours: Wheat and cactus pear (*Opuntia boldinghii* Britton *et* Rose) stems (cladodes). Journal of the Professional Association for Cactus Development 11:78-87.

Moßhammer, M. R., Stintzing, F. C., Reinhold Carle, R., 2006. Cactus pear fruits (*Opuntia* spp.): A review of processing technologies and current uses. Journal of the Professional Association for Cactus Development 8:1-25.

Nataniël. 2002. Food from the white house. Cape Town: Human & Rousseau.

NCSS. 2007. Number Cruncher Statistical System. Statistical System for Windows.

Oelofse, R.M., Labuschagne, M.T., Potgieter, J.P. 2006. Plant and fruit characteristics of cactus pear (*Opuntia* spp.) cultivars in South Africa. Journal of the Science of Food and Agriculture*.* 86, 1921-1925.

Pienaar, H. 2007. The ultimate book of baking. Human and Rousseau Publishers

Piga, A. 2004. Cactus pear: a fruit of nutraceutical and functional importance. Journal of the Professional Association for Cactus Development 6, 9-23.

Saenz, C. 1996. Foods products from cladodes and cactus pear. Journal of the Professional Association for Cactus Development*.* 1:89–97.

Saenz, C. 1997. Cactus cladodes: a source of dietary fibre. Journal of the Professional Association for Cactus Development 2:117–123.

Saenz C. 2000. Processing technologies: an alternative for cactus pear (O*puntia* spp) fruits and cladodes. Journal of Arid Environments 46, 209–225.

Saenz, C. 2013. *Agro-industrial utilization of cactus pear*. Rome. FAO Rural Infrastructure and Agro-Industries Division, in collaboration with the International Technical Cooperation Network on Cactus (FAO–CACTUSNET). Ed. C. Saenz.

Saenz, C., Estévez, A.M., Fontanot, M. 2002. Oatmeal cookies enriched with cactus pear flour as dietary fibre source: Physical and chemical characteristics. Acta Horticulturae 581, 275-278.

Samia El-Safy, F. 2013. Evaluation and utilization of cladodes flour in formulating functional sponge cake. World Applied Sciences Journal 27(4), 512-523. DOI: 10.5829/idosi.wasj.2013.27.04.81117

Stone, H., Sidel, J.L. 2004 Sensory evaluation practices. (3rd ed.). London: Elsevier Academic Press.Utah, USA.