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Impact of Xylitol Replacement on Physicochemical, Sensory and Microbial Quality of Cookies

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Abstract: Effect of replacement of xylitol on physicochemical, sensory and microbiological parameters of cookies were studied. Sucrose was replaced with xylitol at various levels ranging from 25-100%. Physico-chemical, microbiological and sensory evaluation of cookies at different intervals of storage i.e. 0, 15, 30, 45 and 60 days was carried out to find out the best treatment for commercialization. The results pertaining to sensory evaluation of cookies indicated that T_2 (50% sucrose + 50% xylitol) got the highest score for fresh cookies which subsequently decreased but remained the highest during storage after 60 days. There was a significant change in moisture content while non-significant changes were recorded in fat, ash, protein, fiber and NFE contents. In cookies increasing trend in moisture content and decreasing trend in other parameters with storage was observed. Physical analysis revealed that hardness was observed the highest in cookies containing 100% sucrose which decreased significantly with increase in replacement of sucrose with xylitol. Fructurability values increased from cookies containing 100% sucrose to cookies containing 100% xylitol showing that cookies with sucrose were more crunchy. Color and water activity of cookies increased significantly in cookies containing 100% sucrose. It decreased with an increase of xylitol in cookies. Microbiological load was also maximum in cookies having 100% sucrose as compared to cookies containing 100% xylitol.

Key words: Xylitol, replacement, physico-chemical, sensory, microbiological

INTRODUCTION

Low caloric foods available to consumer shelves on the market are products prepared with low energy sweeteners. These products are very popular among weight and health conscious consumers (Abdullah and Cheng, 2001).

Intense sweeteners such as aspartame, cyclamate, saccharine and thaumatin are low energy sweeteners and are used in very small amounts as a sweeteners source in food products. On the other hand, bulk sweeteners provide less energy weight for weight compared to sucrose while having the same bulk volume which includes sorbitol, mannitol, lactitol and xylitol (Bond and Dunning, 2006).

Xylitol has been recently attracting global interest due to its sweetening power equivalent to sucrose. The energy provided by xylitol is only 2.4 kcal/g which is 40% less energy from sucrose. This property makes it a good sugar substitute for producing reduced energy foods (Russo, 1977; Emodi, 1978; Faria *et al.*, 2002).

Moreover, slow adsorption and entry into metabolic pathways independently of insulin and without rapid fluctuation of blood glucose levels, support the use of xylitol as a diabetic sweetener (Rolla *et al.*, 1987).

Xylitol has also some other health benefits as it is regarded as a non-cariogenic sweetener, because it can not be utilized by acid producing bacteria of human oral cavity (Olinger and Pepper, 2001).

At equivalent concentrations, xylitol has a lower water activity than sucrose, contributes to microbial stability and shelf life of a product.

Xylitol has high affinity for water and is more soluble than sucrose at elevated temperature, which allows the formation of very high solid content. This property is very particularly beneficial in hard coating procedure (Bond and Dunning, 2006).

Another remarkable characteristic of xylitol is its negative heat of dissolution which produces a feeling of vaporization in the oral and nasal cavity (Kamijo *et al.*, 1988) and is used in part of confectionary and pharmaceutical products (Pepper and Olinger, 1988) and in the formulation of dietary complements such as amino acids, vitamins and trace elements.

Xylitol exerts a number of beneficial effects as sweetener when used alone or on combination with other sugars in yougurts (Hyvonen and Slotte, 1981), jams (Hyvonen and Torma, 1981), chewing gum (Scheinin *et al.*, 1975; Olinger and Pepper, 2001) and hard candy (Voirol and Brugger, 1976).

In jams, jellies and marmalades sugars acts as a preserving agent, xylitol, in addition to non-fermentability of carbohydrates by mold, yeast and bacteria, is an

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effective agent due to high osmotic pressure even at low temperature.

The pleasant taste profile and cooling effect with no unpleasant aftertaste make it a desirable ingredient for chewing gums (Olinger and Pepper, 2001).

Unlike sucrose, xylitol can not invert in to glucose units. This very positive advantage of xylitol can be used in manufacturing of sweets together with fruit acids without any alteration (Winkelhausen *et al.*, 2007).

In sugar cakes, xylitol proves to be a good substitute for sucrose. The color and texture of xylitol cakes closely resembles those of sucrose cake (Hyvonen and Espo, 1981).

Being a nearly inert substance, it can be heated to melting point (95°C) without causing Maillard browning (Winkelhausen *et al.*, 2007). However, if crust formation, caramalization or non enzymatic browning is required, the addition of reducing sugar is necessary (Olinger and Pepper, 2001).

Considering the beneficial effects of xylitol in other food products, attempt has been made to explore the effect of replacement of sucrose with xylitol on physico-chemical, sensory and microbiological parameters of cookies.

MATERIALS AND METHODS

Procurement of raw material: Raw materials were purchased commercially from local market. Xylitol added in replacement of cookies was prepared in Lab. All the reagents were purchased from Sigma Aldrich.

Chemical analysis of wheat flour: Wheat flour was analyzed for moisture, crude protein, crude fat, crude fiber, nitrogen free extract and total ash content according to the methods described in AACC (2000).

Sample preparation: Cookies evaluated in these experiments were prepared from commercially available flour with sucrose and xylitol in the ratios of 100:0 (T_0), 75:25 (T_1), 50:50 (T_2), 25:75 (T_3) and 100:0 (T_4).

Cookies were prepared according to the method given in AACC (2000) with certain modifications. The recipe followed is flour (500 g), shortening (250 g), sweetener (250 g), eggs (2) and baking powder (5 g).

The ingredients were weighed accurately. Then creaming of shortening and sugar was done, followed by the addition of eggs. The flour and baking powder were added to the creamy mass and mixed to a homogenous mass by mixer (Mod. A-200, Hobart, USA) for 30 min. The batter was then rolled out with rolling pin to a thickness of 3 inches having 1 inch diameter cut with the help of a biscuit cutter. Cookies were placed on a baking tray inch distance and were baked at 425°F in a baking oven for 10 min.

After cooling at ambient temperature, cookies were packed in polyethylene bags and stored for 60 days at ambient temperature. The cookies were analyzed for physical, chemical, sensory and microbiological analysis at 0, 15, 30, 45 and 60 days interval.

Chemical analysis: The cookies were analyzed for moisture, crude protein, crude fat, crude fiber, NFE and ash content according to the methods described in AACC (2000).

Physical analysis

Texture analysis of cookies: Texture of cookies was determined at different storage intervals according to Piga *et al.* (2005) by using a texture analyzer (Mod. TA-XT2 Stable Microsystems, Surrey, UK) with a 5 kg load cell. The Texture Expert program version 1.21 was used for data analysis. Textural determinations were made by using a 3 bend ridge for a bend test. The cookies were bent in order to determine whether any structural was happened as a result of force exerted on cookies. Both the load cell and probes were calibrated before each test. Hardness measurement of samples by bending involved plotting force (g) versus distance (mm). The maximum force (g) was used as an index of hardness for the bend test.

Color measurement of cookies: Color of cookies at different storage intervals was determined according to the method described by Piga *et al.* (2005) with the help of colorimeter (Color Test-II Neuhaus Neotec). The colormeter was calibrated by using standards (54 CTn for dark and 151 CTn for light). The color of the cookies was determined by placing the cookies under the photocell.

Water activity of cookies: Water activity of cookies was determined at different storage intervals by using an electronic hygropalm water activity meter (Model Aw-Win, Rotronic, equipped with a Karl-Fast probe). Hygropalm water activity meter was calibrated and cookies were analyzed according to Piga *et al.* (2005).

Sensory evaluation: The cookies were evaluated by a panel of judges for color, taste, flavor, texture, mouth feel and overall acceptability at 0, 15, 30, 45 and 60 days storage intervals (Meilgaard *et al.*, 1991).

Microbiological analysis: Colony forming unit was carried out by serial dilution according to the method of Awan and Rehman (2005).

Statistical analysis: The data was analyzed by using analysis of variance with the help of statistical package 8.1.

RESULTS AND DISCUSSION

Chemical composition of wheat flour: The results regarding chemical composition of wheat flour indicated that wheat flour contained moisture 11.17%, crude protein 10.15%, crude fat 1.10%, crude fiber 0.29%, ash 0.53% and nitrogen free extract 76.76%. The results are in close agreement with the findings of Pasha *et al.* (2002).

Chemical analysis of cookies: Effect of different treatments on the means of chemical analysis is given in Table 1. There is a significant change in moisture contents from T_0 (3.29) having lowest score to T_4 (4.04) having highest score.

During the storage, cookies showed significant changes in moisture contents and non-significant changes in fat, ash, protein, fiber and NFE contents (Table 2).

The increase in moisture contents and decrease in other parameters during storage was observed in cookies. The increase in moisture contents can be associated with the more hygroscopicity of xylitol than sucrose (Bond and Dunning, 2006). The phenomenon of moisture absorbtion is also supported by Wade (1988). The chemical analysis revealed that moisture content, ash content, crude protein, crude fat, crude fiber and nitrogen free extract were ranging between 3.01-4.08, 0.44-0.45, 6.44-6.45, 23.43-23.44, 0.094-0.1 and 66.19-65.46%, respectively. These results are in close agreement with Pasha *et al.* (2002).

Physical analysis: The mechanical properties of cookies are important when evaluating the quality attributes from the point of view of consumer acceptance. Amongst other things, mechanical characteristics of cookies depend on properties of its matrix.

Results obtained for physical characteristics of cookies are presented in Table 3, 4.

Cookies made with 100% sucrose were significantly harder, drier and crunchier than cookies made with replacement of xylitol. Cookies made with 100% xylitol (T_4) were significantly softer than cookies made with 100% sucrose (T_0).

The hardness of a cookie results in part from the development of a gluten network to form the cookie structure. Gluten must interact with water molecules to promote development of the network, but sugars interfere with this by preferentially attracting water. After the baked cookie cools, sugars may crystallize, which will also contribute to cookie hardness (Taylor *et al.*, 2008). Xylitol, being the more soluble at elevated temperature and hygroscopic than sucrose, has a very high affinity for water and thus interferes the most with gluten development. Xylitol would also crystallize during cooling, less gluten and less crystallization together

Table 1: Effect of different treatments on the means of proximate composition of cookies

Treatments	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Fiber (%)	NFE (%)
T_0	3.29^{d}	23.459	0.458	6.470	0.130	66.193
T_1	3.57^{c}	23.459	0.458	6.467	0.129	65.917
T_2	3.61^{c}	23.457	0.458	6.466	0.128	65.885
T_3	3.82^{b}	23.455	0.456	6.466	0.126	65.675
T_4	4.04^{a}	23.456	0.453	6.463	0.123	65.465

Table 2: Effect of storage period on the means of proximate composition of cookies

Storage (Days)	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Fiber (%)	NFE (%)
0	3.07^{e}	23.460	0.460	6.470	0.130	66.41
15	3.57^{d}	23.459	0.459	6.469	0.129	65.917
30	3.76^{c}	23.458	0.458	6.467	0.128	65.729
45	3.88^{b}	23.456	0.454	6.464	0.126	65.62
60	4.06^{a}	23.454	0.452	6.461	0.124	65.449

Table 3: Effect of different treatments on the means of physical characteristics of cookies

Treatments	Hardness (g)	Fracturability (mm)	Color (CTn)	Water activity (aW)
T_0	2302^{a}	68.76^{e}	172.48^{e}	0.24^{a}
T_1	2163^{b}	70.57^{d}	174.76^{d}	0.23^{b}
T_2	2069^{c}	71.28^{c}	178.71^{c}	0.22^{c}
T_3	2003^{d}	72.43^{b}	184.47^{b}	0.22^{c}
T_4	1832^{e}	73.37^{a}	186.45^{a}	0.20^{d}

Table 4: Effect of storage on the means of physical characteristics of cookies

Storage (Days)	Hardness (g)	Fracturability (mm)	Color (CTn)	Water activity (aW)
0	2127^{a}	70.913^{a}	179.77	0.216^{d}
15	2100^{b}	71.043^{cd}	179.87	0.220^{cd}
30	2064^{c}	71.324^{bc}	179.19	0.226^{bc}
45	2050^{cd}	71.519^{ab}	179.05	0.230^{ab}
60	2027^{d}	71.631^{a}	178.99	0.239^{a}

would result in softer cookies. Olinger and Velasco (1996) also investigated that cookies made with polyols are softer than cookies made with sucrose.

The influence of storage on the physical attributes of cookies is given in Table 4. Hardness of cookies decrease progressively with increase of storage period. Maximum score was observed at 0 days (2127 g). This change can be associated with increase of moisture contents due to more hygroscopicity of xylitol.

Fracturability (Table 3) indicates the crispiness of product. The product having lower value is more crispy than product having high value. Fracturabilty increase from T_0 having lowest score (68.76 mm) to T_4 (73.365 mm) having highest score. This could be attributed to more soft texture of cookies with sucrose than cookies with xylitol. Fracturabilty of cookies is significantly effected by storage (Table 4). Minimum score observed was at zero day which increase gradually with storage period. This change can be associated with the increase of moisture content of cookies.

The color values of the samples are shown in Table 3. These values are indicative of the lightness of samples. Lower color values indicate a darker surface color. The mean values for cookies made with 100% sucrose and 100% xylitol were 172.48CTn and 186.45CTn respectively, which were significantly lower than the mean value for cookies made with 100% sucrose. Xylitol is chemically quite inert because of the lack of an active carbonyl group. It cannot participate in browning reactions. This means that there is no caramalization during heating, as is typical of sugars (Olinger and Pepper, 2001). Because xylitol does not form Maillard reactants, so color of cookies made by replacement of sucrose are lighter in color. Zoulias *et al*. (2000) also observed the same results for polyols. Storage period has non significant influence on the color of cookies (Table 4).

The water activity of bulk sweetener can influence product microbial stability and freshness. Water activity of cookies is given in Table 3. T_0 (0.24) got the highest score while T_4 (0.20) has lowest score.

Owing to its molecular weight, xylitol exerts a higher osmotic pressure and therefore, provides a lower water activity than equivalent solution of sucrose, meaning that it effectively exerts a greater preservative effect in solution than sucrose. This makes xylitol a particularly useful sweetener to increase the solids and therefore, the microbial stability of liquids (Bond and Dunning, 2006). Water activity is significantly effected by storage (Table 4).This change could be due to the hygroscopic nature of xylitol.

Sensory evaluation: Results pertaining to sensory evaluation of cookies are presented in Table 5. Analysis of variance explicit that cookies differed significantly regarding various sensory attributes like color, taste, texture, flavor, mouth-feel and overall acceptability, due to treatments. The results regarding each sensory attribute are discussed one by one.

Treatments have significant effect on color of cookies (Table 5). T_2 got maximum score (8.13) while T_4 obtained the lowest score (4.16). T_0 and T_1 got fairly high score which showed that T_2 (50% sucrose + 50% xylitol) was preferred by the judges because it gave the desired color to the cookies which distinguished it from others, yet T_0 and T_1 were also acceptable. Taste of cookies showed highly significant differences among the treatments. Judges ranked T_2 (7.60) at the first position and T_4 (3.53) at the last position, when averaged over all means. The results concerning with the score for texture of cookies disclosed a highly significant difference among treatments. T_2 got the maximum score 7.86 while T_4 was at the bottom obtaining 4.33 score. Judges placed T_2 (7.86) at the first position and T_4 (4.83) at the last position, when averaged over all means for flavor of cookies. T_2 (6.66) was also favored by the judges. The quality score in response to mouth-feel of the cookies depicted that T_2 got maximum score (7.73) while T_4 obtained the lowest score (5.36). T_1 and T_3 got fairly high score which showed that T_2 (50% replacement of xylitol) was preferred by the judges because it gave the desired mouth-feel to the cookies which distinguished it from others.

Overall acceptability was determined on the basis of quality scores obtained from the evaluation of color, taste, flavor, texture and mouth feel of the cookies. T_2 got the maximum score 7.20 while T_4 was at the bottom obtaining 3.73 score.

The results of this study are in close agreement with the findings of Winkelhausen *et al*. (2007), which reveals that xylitol addition effect sensory properties of cookies. The type and quantity of sweeteners to be added has significant effect on appearance, flavor and texture of biscuits (Matz, 1968).

Storage has significant effect on color of cookies (Table 6). The maximum score 6.80 (Average of 5 treatments) was obtained at 0 days by all the cookies which was significantly decreased as the storage increased. The minimum score of 5.10 (average of 5 treatments) was obtained at 60 days storage. The deterioration in color of biscuits might be due to the absorption of moisture from the atmosphere and oxidation of fats. These results are in close agreement with the findings of Iftikhar (2002).

As regarding taste of cookies, maximum score was obtained by fresh cookies (0 days) which was gradually decreased with storage days. The range between 0 days and 60 days was 6.60-4.66.

The results concerning with the score for texture of cookies disclosed maximum score was obtained by fresh cookies (0 days) which was gradually decreased with storage days. The range between 0 day and 60 days was 6.73-4.33. Winkelhausen *et al*. (2007) also

Table 5: Effect of different treatments on the means of sensory characteristics of cookies

Treatments	Color	Taste	Texture	Flavor	Mouth-feel	Overall acceptability
T_0	6.06^c	5.53^{bc}	6.00^c	6.20^{bc}	5.93^{cd}	5.66^c
T_1	7.73^b	6.00^b	6.73^b	6.66^b	6.40^{bc}	6.40^b
T_2	8.13^a	7.60^a	7.86^a	7.86^a	7.73^a	7.20^a
T_3	4.80^d	5.60^c	5.06^d	5.86^c	6.66^b	4.46^d
T_4	4.16^e	3.53^d	4.33^e	4.83^d	5.36^d	3.73^e

Table 6: Effect of storage period on the means of sensory characteristics of cookies

Storage (Days)	Color	Taste	Texture	Flavor	Mouth-feel	Overall acceptibilty
0	6.80^a	6.60^a	6.73^a	7.20^a	7.33^a	6.20^a
15	6.53^a	5.90^b	6.50^a	6.73^a	6.80^a	5.96^{ab}
30	5.93^b	5.46^{bc}	6.13^{ab}	6.13^b	6.36^{bc}	5.66^{ab}
45	5.53^{bc}	5.10^{cd}	5.63^b	5.96^b	6.00^{cd}	5.10^c
60	5.10^c	4.66^d	5.00^c	5.40^c	5.60^d	4.53^d

Table 7: Effect of xylitol on microorganism of cookies

	Treatments (CFU/g)					
Storage (Days)	T_0	T_1	T_2	T_3	T_4	Means
0	0	0	0	0	0	0
15	45	39	32	28	22	33
30	102	98	92	88	70	90
45	160	139	122	120	93	127
60	216	196	160	134	118	164
Means	105	94	81	74	61	

found the significant effect of storage on texture of cookies made with xylitol.

Flavor of cookies disclosed that maximum score was obtained by fresh cookies (0 days) which was gradually decreased with storage days. The range between 0 days and 60 days was 7.20-5.40. The loss in flavor might be attributed to absorption of water that resulted in fat oxidation.

The quality score in response to mouth-feel of the cookies depicted that maximum score 7.33 (Average of 5 treatments) was obtained all the fresh cookies (0 days) which was decreased significantly as the storage increased. The minimum score of 5.60 (average of 5 treatments) was obtained at 60 days.

Overall acceptability was determined on the basis of quality scores obtained from the evaluation of color, taste, flavor, texture and mouth feel of the cookies.

Analysis of variance disclosed a highly significant effect of storage on overall acceptability of cookies. As a whole the maximum score was obtained by fresh cookies (0 days) which gradually decreased with storage days. The range between 0 days and 60 days was 6.20-4.53. In earlier studies, a gradual decrease in overall acceptability of biscuits during storage was reported by Pasha *et al*. (2002) who attributed it to moisture absorption, increase in peroxide value and free fatty acid contents in biscuits.

Microbiological analysis: Microbiological evaluation, as an objective and widely used test in studying the food quality, was performed. The results of microbiological tests are presented in Table 7. The cookies made with replacement of xylitol had lower microbial load than cookies made with sucrose. The number of CFU decrease among treatments from T_0 having highest CFU to T_4 having lowest number of CFU. The analysis of freshly made cookies showed no growth at zero day. However, the number of CFU increased with storage period. The maximum number of CFU were at 60 days in T_0 (100% sucrose), while T_4 (100% xylitol) had least microbial load at 60 days.

The presence of low number of CFU in the cookies made with replacement of xylitol is associated with rather rare ability of microorganisms to metabolize xylitol compared with the microbial utilization of hexoses (Winkelhausen and Kuzmanova, 1998). In view of these observations, the baked products with xylitol are not only microbiologically safe but their shelf-life could be much longer too.

Conclusion: The present study demonstrated that the cookies containing xylitol in replacement of sucrose are sensorially acceptable and microbiologically safe with tendency to have extended shelf-life. This makes xylitol not only promising sugar substitute but alternative sweetener with real practical applicability in this type of products.

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