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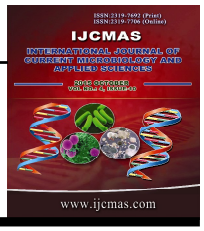

Original Research Article

Modification of Potato Starch by Some Different Physical Methods and Utilization in Cookies Production

Nadir, A.S.*, Helmy, I.M.F., Nahed, M. Abdelmaguid, Wafaa, M. M. Abozeid and Ramadan, M.T.

Food Technology Department, National Research Centre, Egypt
**Corresponding author*

Keywords

Potato starch, Heat-moisture treatment (HMT), Microwave, Ultrasonication, Syneresis, Cookies

A B S T R A C T

Native starch samples were prepared from potato tubers and modified by heat-moisture treatment (HMT), microwave, ultrasonication and syneresis methods. All modification methods reduced contents of protein, fat, ash and amylose but increased Amylopectin content in modified potato starch samples compared with those of native starch. Both HMT and microwave methods improved water absorption capacity (WAC) (g/g). While, all modification methods tend to reduce swelling power (g/g) in modified potato starch samples. The value of solubility (%) of modified starch with ultrasonication method (14.82%) was higher than that present in native starch (13.25%). Microwave modification method increased values of pasting temperature (^{o}C), Pv (peak viscosity during heating), Hv (hot paste viscosity at 95^{o}C), Hv_{30} (viscosity after 30 min holding at 95^{o}C) and Cv (cold paste viscosity at 50^{o}C) in this modified starch sample compared with those of native starch sample. All pasting properties values of two modified starch samples with ultrasonication and syneresis except BD (break down) values were lowered. Color results of different starch samples showed that, all modification methods lowered values of lightness (L), yellowness (b), saturation and hue while, redness (a) values were increased and color difference (ΔE) value was ranged to its highest in potato starch sample modified by microwave method. Results of chemical composition for cookies indicated high values of protein in all cookies samples modified by all modification methods used and high carbohydrates content in cookies samples modified by HMT, ultrasonication and syneresis methods. Color results of different cookies samples showed that, the lowest values of lightness (L), yellowness (b), saturation and hue were found in cookies sample made from potato starch modified with microwave where, the highest values of redness (a) and color difference (ΔE) were present also in the same last sample. All physical characteristics of cookies samples made from all modified potato starches were increased and these samples had high values for all sensory characteristics evaluated and also high score values compared to the cookies sample made from native potato starch.

Introduction

Potato starch is a highly versatile raw material in the manufacture of both food (for example bakery products, sugar syrups, confectionery, snack foods and meat products) and non-food products (Copeland *et al.,* 2009). It has its own distinctive physic-chemical, thermal and rheological characteristics and is sufficiently bland to be incorporated easily into food preparations (Jobling, 2004). Native starches usually don't meet industrial needs in which starch should be able to with stand low acidity, high temperatures and high shear forces (Varatharajan *et al.,* 2010). Consequently, starches have been modified physically by heat-moisture treatment, microwave, ultrasonication, multiple freezing and thawing and iterated syneresis methods (Lim *et al.,* 2001; Lewandowicz and Soral-Smietana, 2004; Szymonska and Wodnicka, 2005; Anderson and Guraya, 2006; Lida *et al.,* 2008).

Heat-moisture treatment (HMT) is physical modification that changes the physicochemical properties of starch, without destroying its granule structure. Heat –moisture treatment is related process in which the starch to moisture ratio, the temperature and heating time are critical parameters that need to be controlled (Chung *et al.,* 2009). It is carried out under restricted moisture content (10–30%) and higher temperatures (90–120^{o}C) for a periods ranging from 15 min to 16 h (Maache-Rezzoug *et al.,* 2008). Studies have been conducted on the effect of microwave heating on a variety of food substances (Khraisheh *et al.,* 2004) evaluated the quality and structural changes in starchy foods during microwave and convective drying and reported reduced vitamin C destruction but a higher rehydration potential in microwave dried samples.

Application of power ultrasound has immense potential for a wide variety of processes in the food industry which include extraction, crystallization, filtration, emulsification and more. Controlling the viscosity of starch (polysaccharide) solutions is one of the most promising processes to be developed. Power ultrasound can effectively gelatinize at high starch concentration (20–30%). Starch gel can be liquidized by sonication (Lida *et al.,* 2008).

Multiple deep freezing and thawing of granular potato starch altered the water distribution in the granules (Szymonska *et al.,* 2003) and significantly increased the granule surface coarseness (Szymonska *et al.,* 2000 and Szymonska and Krok, 2003). The process of iterated synersis applied to modification of potato, tapioca, corn and wheat starches resulted in a new type of physically modified starches that contained the resistant starch (RS) fraction of unique physicochemical properties (Lewandowicz and Soral-Smietana, 2004).

Therefore, this study was carried out to extract starch from potato tubers and modify it physically by several methods such as heat-moisture treatment (HMT), microwave, Ultrasonication and syneresis, determine the chemical composition, functional properties, pasting characteristics and color of different starch samples. Also, use it in cookies production with chemical, color, physical characteristics and sensory evaluation.

Materials and Methods

Materials

Potato tubers (*Solanum tuberosum L.*) were obtained from Giza local market, Egypt. All other reagents were used in this work were analytical grade.

Preparation of native potato starch

Potato tubers were washed, peeled, sliced into 2-3 cm cubes and soaked in distilled water contained 20 mM sodium bisulphate and 10 mM citric acid for 2h. The cubes were then disintegrated using a centrifugal juice extractor. The pulp was suspended in distilled water, and the starch milk was collected. The milk was allowed to sediment for a minimum of 30 min, after which the suspended solids were removed by decantation and the starch sediment was resuspended in water. The starch granules were recovered by vacuum filtration, and washed a minimum of three times and finally, ambient air-dried. The dried starch was passed through a 125 µm sieve, packed in air-tight plastic bags and stored at room temperature until further use (Liu, 1997).

Preparation of modified potato starches

Potato starch samples were modified physically by different methods:

Heat-moisture treatment (HMT)

Water was sprayed onto powdery native potato starch to adjust its moisture content to 20-25% as described by the method of (Lim *et al.*, 2001). The starch/water mixture was extensively mixed with a blender and then the exact moisture content of the mixture was measured.

The moisture adjusted starch (200g) was transferred to a glass beaker and conventionally heated in an electric oven at 120^{o}C for 1h.

After the HMT, the starch was dried to approximately 10% moisture content in a convection oven (40^{o}C) overnight. The sample ground and sieved through a 60 mesh screen in plastic bags and stored at room temperature.

Microwave method

Native potato starch (100g) was irradiated according to the method described by Staroszczyk (2009) in beaker using microwave (Goldstar model. No. ER-535 Mo, 2450 MHz, 980w, Korea) for 30 min at 450 w followed by air cooling to room temperature. Sample was further ground with mortar and pestle and sieved through a 60 mesh screen in plastic bags and stored at room temperature until further use.

Ultrasonication method

Native potato starch sample was modified by ultrasonication method as described by Lida *et al.* (2008) 500g of starch slurry (10% solids of native potato starch) were heated at 90^{o}C for 60 min in a glass vessel with a mantle heater for uniform heating. Starch paste, thus prepared was cooled down to 60^{o}C. Sonication with bath type equipment (Wiseclean, cleaner ultrasonic digital, 6 lit. model WUC-D06H, 220V Lab-instruments 425 watts. 60Hz made by Daihan scientific co., Ltd., Korea) was utilized for sonicating the starch paste; 500g of sample paste was sonicated for 30 min with mechanical stirring for achieving homogeneous irradiation of ultrasound to the sample. The output energy was usually set to 100w and the paste sample was cooled at room temperature by air, ground and sieved through a 60mesh screen in plastic bags and stored at room temperature until further use.

Synersis method

Physically modified starch samples was obtained by solubilization of native starch sample in water at concentration of 3%, and by their isolation from the solution to procedure described by Lewandowicz and Soral-Smietana (2004) to this end commercial native potato starch was

solubilized in water at a temperature of 90^{o}C for 4h, then left in water at room temperature for 24h and frozen to a temperature below -4^{o}C. The frozen sample was allowed to thaw at room temperature, and then the liquid and solid phases were separated by filtration. The moist solid phase was frozen again and the frosting/thawing cycles were repeated until the moisture content of the solid phase was below 20% followed by air cooling to room temperature, ground with mortar and pestle and sieved through a 60 mesh screen in plastic bags and stored at room temperature until further use.

Analytical methods:

Moisture, protein, fat, ash and amylose content of the different starch samples were determined according to the methods described in A.O.A.C. (2005). Amylopectin content was determined by difference (100 – amylose %). Total carbohydrates were calculated by difference in gross chemical composition of cookies.

Water and oil absorption capacity of native and modified potato starches:

Water absorption capacity (WAC) and oil absorption capacity (OAC) of the native and modified starches were determined following method of Beuchat (1977). Water or oil absorption capacities were expressed as gram of water or oil bound per gram of dry starch.

Swelling power and solubility

The swelling power and solubility of the starches were determined according to the method described by Adebowale *et al.* (2009) 500mg of starch sample was weighed into a centrifuge tube and it was reweighed (W_1). The starch was then dispersed in 20ml of water. The mixture was centrifuged at 3000g for 15min. supernatant was decanted carefully and residue weighed for swelling power determination. Weight of dry centrifuge tube, the residue and the water it retained was taken as W_2.

$$\textbf{Swelling power} = \frac{W2-W1}{\text{Weight of starch}}$$

Aliquots (5ml) of supernatant were dried to a constant weight at 110^{o}C. The residue obtained after drying the supernatant represented the amount of starch solubilized in water. Solubility was calculated as g per 100g of starch on dry weight basis.

Color evaluation

Color differences of starch and cookies samples were measured by using a spectro-colorimeter (Tristimulus color machine) with CIE Lab Color scale (Hunter, Lab Scan XE, Reston VA.) calibrated with a white standard tie of Hunter Lab color standard (LX No. 16379): X=77.26, y=81.94 and z=88.14 (L*=92.36, a*=-0.82, b*= -0.14). Color difference (ΔE) was calculated from a, b and L parameters, using Hunter-Scot field's equation (Hunter, 1975) as follows:

$\Delta E = (\Delta a^2+\Delta b^2+\Delta L^2)^{1/2}$
Where $a = a-a^0$, $b=b-b^0$ and $L=L-L^0$.
Subscript "O" indicates color of the control.
Hue angle (t_g^{-1} b/a) and saturation index ($\sqrt{a^2+b^2}$) were also calculated.

Pasting properties

Pasting properties of different starch paste samples (native and modified) (8%, 36 g of starch on dry weight basis in 450 ml of water) were measured using Brabender viscoamylograph equipped with 700g.cm sensitivity cartridge, using a method

previously described by Osunsami *et al.* (1989). The starch suspension was heated from 50-95^{o}C. It was kept at this temperature for 30 min, then cooled to 50^{o}C and held at this temperature for 30 min. the speed of rotor was fixed at 75 rpm and the heating as well as cooling rate was 1.5^{o}C per minute throughout the range of gelatinization holding and cooling steps. The parameters determined were pasting temperature (Tp), peak viscosity (Pv), hot paste viscosity (H_V), hot paste viscosity after 30 min holding at 95^{o}C (Hv_{30}), cold pate viscosity (Cv), while set back (SB) and break down (BD) of the starch samples were calculated and reported as Brabender units (BU).

Preparation of cookies

Cookies were prepared according to A.A.C.C. (2010). 100g starch (native or modified with different methods), a shortening (9.64g), salt (2.02g), sodium bicarbonate (0.16g), yeast (3.48g) and the content of water was expressed based on the type of starch used in the blend.

Baking quality

Weight (g), height (cm), volume (cm^3), specific volume (cm^3/g), diameter (cm), and spread ratio (diameter/height) were calculated for each sample according to the method described by Kulp *et al.* (1985).

Sensory evaluation and statistical analysis

Appearance, color, texture, flavor and taste of produced cookies samples were evaluated organoleptically as described by Colombo *et al.* (2008) using panel of ten well-trained judges selected from the staff of Food Science and Technology Department, NRC. The results were statistically analyzed by analysis of variance and least significant difference (LSD) at 0.05 level as reported by Gomez and Gomez (1984).

Results and Discussion

Chemical composition of potato starch samples

Data in table 1 indicated that, native potato starch sample was higher slightly in protein, fat and ash contents than other samples of potato starch modified by all different methods of modification. HMT and microwave modification methods reduced the contents of protein, fat and ash for modified potato starch samples which were ranged from 0.28-0.33%, 0.17-0.18% and 0.34-0.37% respectively as compared with the same contents found in native potato starch sample. Also, it could be seen that, great reduction was noticed for the last contents in modified potato starch samples by ultrasonication and synersis methods.

Amylose content reached to its highest value in native potato starch sample (27.60%) compared to starch samples modified by other methods. Values of Amylopectin were increased by all starch modification methods were used. Potato starch samples modified by HMT and ultrasonication had 74.28 and 74.06% amylopectin respectively which were the highest from between the other starch samples. These results are in agreement with those obtained by Lewandowicz and Soral-Smietana (2004), Jimenez-hernandez *et al.* (2007) and Varatharajan *et al.* (2010). They stated that, the procedure of physical modification change slightly the chemical composition of the investigated starches.

Functional properties

The functional properties of native potato starch sample and modified starch samples

by different methods are shown in table 2. Both potato starch samples modified by HMT and microwave methods had the highest values of water absorption capacity (WAC) (0.78g/g and 0.75g/g) respectively. While, oil absorption capacity (OAC) from starch samples modified by the same methods had lower values (0.57g/g and 0.60g/g) respectively than found in native starch sample (0.65g/g). Modification methods such as ultrasonication and synersis caused a reduction in values of water and oil absorption capacities of native starch sample by 4.84 to 12.90% and by 18.46 to 26.15% respectively. Results of swelling power showed that, there was a low values in all modified potato starch samples and ranged from 44.92 to 49.73 (g/g). ultrasonication method had a positive effect on solubility values which was increased to 14.82% while, the other three modification methods reduced the solubility values of their modified starch samples as compared with native sample. Heat-moisture conditioning reduced the solubility and swelling capacity of the native starch. Also, this treatment enhances the water absorption capacity (WAC) of the starch due to the hydrophilic tendency increased with increased level of moisture treatment.

On the other hand, HMT caused a reduction in hydrophobic tendency of the native starch which decreased oil absorption capacity (OAC) Adebowle *et al.* (2009). Similar trend of results were obtained by Szymonska *et al.* (2003) who reported that, water solubility and water holding capacity estimated for the potato starch samples, were slightly higher after the first freezing step and then decreased after subsequent cycles. Also Lida *et al.* (2008). Reported that, the results clearly show the effectiveness of sonication for the solubilization of potato solution after the gelatinization.

Pasting properties

Results in table 3 show the pasting properties of native and modified potato starch samples by different methods. HMT and microwave methods caused an increasing in initial pasting temperature (T_P) value of native potato starch from 61 to 63 and 65^{o}C respectively while, the two other modification methods tend to reduce initial pasting temperature (T_P) value of native potato starch to 56 and 55.2^{o}C for ultrasonication and synersis methods used respectively.

Reduction was noticeable in values of peak viscosity (Pv), hot paste viscosity (Hv) at 95^{o}C, viscosity after 30 min holding at 95^{o}C (Hv_{30}) and cold paste viscosity at 50^{o}C (Cv) in native potato starch samples treated by ultrasonication and synersis methods. Also, it could be noticed in the same table that, the same last parameters were tended to increase in native potato starch samples modified by microwave method. Results of pasting properties in starch sample modified with HMT revealed that, Pv and Hv were lowered to 1295 and 1280 (BU) respectively; Hv_{30} and Cv values for the last same sample were increased to 1300 and 1610 (BU) as compared with the same parameters found in native starch sample. On the other hand, the set back value (SB) was decreased for the native potato starch sample modified by HMT, ultrasonication and synersis methods compared with native sample while, it was raised with modification by microwave method. The break down (BD) values of native potato starch samples modified by all forms of modification methods studied except HMT method were higher than that of unmodified potato starch sample (native). The HMT-induced reduction in breakdown demonstrates that starches are more stable during continuous heating and agitation, which is supported by Adebowale *et al.*

(2005) and Olayinka *et al.* (2008). These results are in agreement with those reported by Lewandowicz and Soral-Smietana, 2004; Anderson and Guraya, 2006 and Adebowale *et al.* (2009).

Color values of different potato starch samples

The color measurements of native and modified potato starch samples are presented in table 4. Results showed that potato starch samples modified by all modification methods had lower values of lightness (L) and yellowness (b) than present in native starch samples. There was an increasing in values redness (a) for all modified starch samples which were higher than found in native starch sample. All modification methods of potato starch samples caused a noticeable reduction in saturation and hue values. Great changes in color difference (ΔE) values occurred in modified starch sample by microwave method. These results are in agreement with those obtained by Ali *et al.* (2012) and Falade and Ayetigbo (2015). They reported that, changes in color values during starch modification with physical methods such as heat-moisture treatment (HMT) could be due to the purification and separation of some heterogeneous materials such as proteins, salts, sugars and other elements.

Chemical composition of cookies

Chemical composition of cookies made from different samples of potato starch is shown in table 5. It could be concluded that, protein content of cookies samples made from modified starch by all modification methods used in this study was increased slightly from that made from native potato starch (control). All cookies samples contained fat and ash content ranged between 12.50-13.98% and 0.33-0.40% respectively. Cookies samples made from native potato starch and HMT contained high values of fat 13.98 and 13.84%; respectively. While, ash content increased to its highest value 0.40% in cookies sample made from modified potato starch by microwave method.

From results in the same table, it could be observed that, carbohydrate contents for cookies samples made from native, modified by HMT and microwave potato starches were relatively similar (73.65, 73.71 and 73.49%) respectively but it increased to 74.78 and 74.97% in cookies samples made from modified potato starch by Ultrasonication and syneresis methods respectively. These results are in agreement with those obtained by Wafaa *et al.* (2012). They reported that, banana, potato and wheat starches were suitable for incorporation into products such as bakery products.

Color values of cookies samples

Hunter color values of cookies samples produced from native potato starch sample and other modified potato starch samples are presented in table 6. All modification methods reduced values of lightness (L) except cookies sample made from starch modified by synersis method and yellowness (b) values for all cookies samples modified starch samples modified by all methods of modification used compared with cookies sample made from native starch. Samples of cookies made from starch modified by HMT, microwave and ultrasonication methods had high values of redness (a). The opposite trend was observed in saturation values for all cookies samples produced from potato starch modified by all methods used. Modification of potato starch by synersis method tends to improve Hue value of cookies sample made from it.

Table.1 Gross chemical composition of potato starch samples (native and modified) by different methods on dry basis

Starch samples	Moisture%	Protein%	Fat%	Ash%	Amylose%	Amylopctin%
Native potato starch	10.62±0.11	0.40±0.02	0.20±0.01	0.38±0.04	27.60±0.51	72.40±1.22
Potato starch modified with HMT*	12.19±0.52	0.33±0.03	0.17±0.08	0.34±0.01	25.72±0.44	74.28±1.51
Potato starch mo dified with microwave	6.95±0.38	0.28±0.05	0.18±0.06	0.37±0.02	26.29±0.51	73.71±1.41
Potato starch modified with Ultrasonication	12.08±0.41	0.22±0.07	0.08±0.03	0.26±0.05	25.94±0.34	74.06±1.31
Potato starch modified with synersis	13.24±0.33	0.17±0.04	0.10±0.02	0.30±0.03	26.18±0.48	73.82±1.20

*HMT = heat-moisture treatment *all values are means of triplicate determinations ± standard deviation

Table.2 Functional properties of native and modified potato starch samples

Starch samples	Water absorption capacity (WAC) g/g	Oil absorption capacity (OAC) g/g	Swelling power (g/g)	Solubility (%)
Native potato starch	0.62±0.07	0.65±0.10	52.81±0.19	13.25±0.15
Potato starch modified with HMT*	0.78±0.11	0.57±0.03	44.92±0.21	12.67±0.12
Potato starch modified with microwave	0.75±0.09	0.60±0.05	49.73±0.23	11.40±0.13
Potato starch modified with Ultrasonication	0.54±0.08	0.48±0.06	45.32±0.16	14.82±0.18
Potato starch modified with synersis	0.59±0.04	0.53±0.09	47.64±0.24	12.54±0.14

*HMT = heat-moisture treatment *all values are means of triplicate determinations ± standard deviation

Table.3 Pasting properties of native and modified potato starches by different methods

Starch samples	Tp* ^{o}C	Pv* (BU*)	Hv* (BU)	Hv_{30}* (BU)	Cv* (BU)	SB* (BU)	BD* (BU)
Native potato starch	61	1330	1315	1270	1515	280	30
Potato starch modified with HMT*	63	1295	1280	1300	1610	220	25
Potato starch modified with microwave	65	1370	1350	1330	1670	300	40
Potato starch modified with Ultrasonication	56	1010	980	965	1200	190	45
Potato starch modified with synersis	55.2	940	910	890	1115	175	50

*HMT = heat-moisture treatment *Tp=initial pasting temperature *Hv=hot paste viscosity *Hv_{30}= viscosity after 30 min holding at 95^{o}C *Cv=cold paste viscosity at 50^{o}C *SB=set back value=Cv-Pv *BD=break down=Pv- Hv_{30} Pv= peak viscosity during hating BU= Brabender unit

Table.4 Color values of different potato starches samples

Starch samples	L*	a*	b*	a/b	Saturation	Hue	ΔE
Native potato starch	69.45	2.28	14.73	0.15	14.91	81.20	——
Potato starch modified with HMT*	63.71	4.19	10.28	0.41	11.10	67.82	7.51
Potato starch modified with microwave	58.23	5.60	8.37	0.67	10.07	56.22	13.32
Potato starch modified with Ultrasonication	65.80	3.76	11.51	0.33	12.11	71.91	5.09
Potato starch modified with synersis	67.39	3.10	12.23	0.25	12.62	75.78	3.31

HMT = heat-moisture treatment L= lightness a*= redness b*= yellowness ΔE= color of difference

Table.5 Gross chemical composition of cookies

cookies samples	Moisture%	Protein%	Fat%	Ash%	Total carbohydrates%
cookies made from Native potato starch	5.17±0.32	12.00±1.28	13.98±1.34	0.37±0.02	73.65
cookies made from Potato starch modified with HMT*	7.52±0.43	12.11±1.31	13.84±1.31	0.34±0.01	73.71
cookies made from Potato starch modified with microwave	4.36±0.38	12.43±1.21	13.68±1.25	0.40±0.06	73.49
cookies made from Potato starch modified with Ultrasonication	6.70±0.41	12.28±1.22	12.59±1.27	0.35±0.07	74.78
cookies made from Potato starch modified with synersis	7.86±0.61	12.20±1.20	12.50±1.23	0.33±0.09	74.97

*HMT = heat-moisture treatment *all values are means of triplicate determinations ± standard deviation

Table.6 Color values of cookies samples produced from native and modified potato starches

cookies samples	L*	a*	b*	a/b	Saturation	Hue	ΔE*
cookies made from Native potato starch	54.40	3.72	39.64	0.09	39.81	84.64	——
cookies made from Potato starch modified with HMT*	50.68	5.31	34.52	0.15	34.93	81.26	6.53
cookies made from Potato starch modified with microwave	47.92	6.42	31.75	0.20	32.39	78.57	10.56
cookies made from Potato starch modified with Ultrasonication	53.87	4.30	36.60	0.12	36.85	83.30	3.14
cookies made from Potato starch modified with synersis	56.09	2.98	38.32	0.08	38.44	85.55	2.27

HMT = heat-moisture treatment L= lightness a*= redness b*= yellowness ΔE*= color of difference

Table.7 Physical characteristics of cookies made from different samples of potato starch

cookies samples	Diameter (cm)	Height (cm)	Volume (cm3)	Weight (g)	Specific volume (cm3/g)	Spread ratio (diameter/height)
cookies made from Native potato starch	7.20±0.08	1.32±0.02	40.50±0.06	17.20±0.03	2.35±0.07	5.45±0.05
cookies made from Potato starch modified with HMT*	7.24±0.06	1.35±0.05	41.48±0.08	17.56±0.05	2.36±0.09	5.36±0.06
cookies made from Potato starch modified with microwave	7.29±0.05	1.38±0.09	42.29±0.07	17.87±0.06	2.37±0.02	5.28±0.04
cookies made from Potato starch modified with Ultrasonication	7.32±0.04	1.42±0.06	43.47±0.04	18.39±0.08	2.36±0.03	5.15±0.09
cookies made from Potato starch modified with synersis	7.36±0.03	1.46±0.11	44.68±0.06	18.89±0.04	2.37±0.10	5.04±0.12

*HMT = heat-moisture treatment *all values are means of triplicate determinations ± standard deviation

Table.8 Sensory evaluation of cookies samples made from different potato starches

cookies samples	Appearance	Color	Texture	Flavor	Taste	Total score
cookies made from Native potato starch	$8.3^{b}\pm0.22$	$9.0^{b}\pm0.61$	$8.4^{b}\pm0.40$	$8.6^{b}\pm0.12$	$8.1^{c}\pm0.39$	42.4
cookies made from Potato starch modified with HMT*	$8.6^{ab}\pm0.44$	$9.2^{ab}\pm0.46$	$8.6^{ab}\pm0.31$	$8.7^{b}\pm0.41$	$8.5^{bc}\pm0.30$	43.6
cookies made from Potato starch modified with microwave	$9.0^{a}\pm0.42$	$9.4^{a}\pm0.35$	$8.8^{a}\pm0.23$	$9.0^{ab}\pm0.58$	$8.7^{b}\pm0.21$	44.9
cookies made from Potato starch modified with Ultrasonication	$9.2^{a}\pm0.52$	$9.6^{a}\pm0.20$	$9.1^{a}\pm0.56$	$9.3^{a}\pm0.24$	$9.0^{ab}\pm0.60$	46.2
cookies made from Potato starch modified with synersis	$9.4^{a}\pm0.33$	$9.8^{a}\pm0.24$	$9.3^{a}\pm0.21$	$9.6^{a}\pm0.42$	$9.5^{a}\pm0.22$	47.6
$LSD_{0.05}$	0.92	0.75	0.98	0.72	0.52	

*HMT = heat-moisture treatment *Any two means have the same letters at the same column aren't significant different at $P\leq0.05$

On the other hand, color difference (ΔE) reached to low value 2.27 and high value 10.56 in cookies samples contained starch modified by syneresis and ultrasonication methods respectively. These results are in agreement with those reported by Chevallier *et al.* (2000) and Brannan *et al.* (2001). They reported that, it has a negative correlation between the protein content and the whiteness (L). Also, the oil absorption effect and Millard reaction between protein and inverse sugar in the presence of baking heat.

Physical characteristics of cookies

Physical characteristics of cookies made from native and modified potato starches by different methods are shown in table 7. It could be noticed that diameter, height and specific volume values of cookies made from all types of modified starch were increased slightly compared with that made from native starch (control). While, values of volume and weight for cookies samples increased compared to control as different modified starches were used. Highest values of spread ratio were observed in cookies made from native starch. Cookies samples contained modified starches had lower spread ratio values than the cookies sample mad from native starch. This could be attributed to the partial degradation of starch by yeast during fermentation resulting in increased dextrins which may have a greater water binding capacity in dough, thus restricting cookies spread during the baking

process. These results are in agreement with Helmy and Esmat (2000).

Sensory characteristics of cookies

Data presented in table 8 show the sensory evaluation of cookies samples made from potato starches (native and modified by different methods). Results showed that, cookies samples made from all modified potato starches had high values for all sensory characteristics evaluated compared with cookies sample made from native potato starch. Also, it could be noticed from the same table that, cookies samples made from modified potato starch by syneresis method were the highest in total score (47.6) while, cookies sample made from native potato starch was the lowest (42.4). There was no significant difference in appearance, color and texture between cookies samples made from modified potato starches by microwave, ultrasonication and syneresis methods and cookies sample made from potato starch modified by HMT. Also, the same observation for the last same characteristics were found between cookies sample made from native potato starch and cookies made from modified potato starch by HMT. In regard to flavor, no significant differences were detected in cookies samples made from native and HMT modified potato starches. Cookies samples made from other samples potato starches modified by ultrasonication, microwave and syneresis methods, had no significant differences in flavor. Cookies samples from potato starches modified by HMT, microwave and ultrasonication methods had no significant differences between them in taste. Significant differences were occurred between cookies samples made from native and modified potato starches by syneresis method.

In conclusion, Native starch obtained from potato tubers was subjected to different modification methods such as HMT, microwave, ultrasonication and syneresis. HMT and microwave methods increased water absorption capacity (g/g) while, swelling power (g/g) was reduced in all modified starch samples, all values of pasting properties were increased in modified starch sample with microwave method and the opposite trend was found in samples modified with ultrasonication and syneresis methods compared with those in native potato starch. Results of physical characteristics and sensory evaluation of cookies samples made from potato starch modified by all modification methods indicated that, all modified starches are suitable as a supplemented materials for producing and improving food products like bakery products**.**

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