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Chemical and Technological Characteristics of White Dent Maize (*Zea mays* Var. *Identata*) Grains as Affected by Different Treatments. 1-Effect of Boiling, Nixtamalization and Soaking Treatments on Some Chemical Characteristics of White Dent Maize Grain whole Flour

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Abstract: This study was carried out for chemical composition, phosphorus fractions, polyphenolic compounds, some minerals and thermal properties of starch in white dent maize whole flour (Variety Single Hybrid Giza 10) as affected by boiling, soaking and nixtamalization. The results of chemical composition showed that the UM flour had the highest contents of ash (1.46), oil (4.93) and caloric value (404.25 kcal/100g). Also, there were significant differences between the control and the treated samples, either increase or decrease in the contents of protein, crude fiber and total carbohydrates, which varied between 8.09-9.84%, 2.96-3.71% and 81.22-83.85% for all studied samples, respectively. The phosphorus factions in maize samples were studied. From the obtained results, there were highly significant decreases in the values of total phosphorus (Tp), phytate phosphorus (Pp) and phytic acid in treated maize samples. The phytic acid content in the treated samples decreased significantly with percentages from 5.63% to 54.08% due to the nature of the treatment itself. There was a significant decrease in the total and bound phenolic contents of all the treated samples due to boiling, soaking and nixtamalization, with values ranged from 242.38 to 298.63%; from 233.87 to 292.32% when compared with control values 307.38% and 302.01%, respectively. The boiling, soaking, nixtamalization process significantly increases the calcium content of maize samples except BM30min it decreased. The starch content of studied samples was ranged from 55.81% to 69.83%. The gelatinization temperatures and enthalpies varied significantly between whole maize flours under study. The onset temp (To) was ranged from 30.56 to 42.37°C, while peak temp (Tp) ranging from 70.83 to 80.56°C as compared to 40.98°C and 80.56°C for Um sample, respectively. The ΔHP content ranging from 3.76 to 4.38J.g^{-1} for all the studied flours with small significant difference between the treated and Um sample. From these results it concluded that treated whole maize flour has a good quality which better than untreated in processing of bread.

Key words: Starch · DSC · Total Carbohydrates · Polyphenolic Compounds and Whole Flour

INTRODUCTION

Corn (*Zea mays* L.) is the main cereal grain as measured by production, but ranks third as a staple food, after wheat and rice. The reasons for this fact are varied, but some of them are related to cultural or social preferences and also because in some countries, corn is cultivated as livestock feed. In many countries of the world such as India, China, Spain, France and Greece maize grains used to treat kidney stones, urinary tract infections, jaundice and fluid retention. It also has a potential to improve blood pressure, support liver functioning, produce bile and helps to improve the functioning of the thyroid gland and immune system. It acts as a good emollient for wounds, swelling and ulcers [1].

The varieties of corn are defined according to the type of kernel type: dent, flint, waxy, flour, sweet, pop, Indian and pod corn. Dent maize with flinty sides and soft cores of starch that cause the end of the grains to collapse or dent during drying it is very popular in human food products like cooking oil, meals, flour starches and sweeteners [2].

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The maize products require additional processing before consumption. These processes may include the addition of other ingredients along with thermal processing, including boiling, drying, frying, baking or nixtamalization, all of which can affect the nutritional attributes of the finished product [3, 4].

Nixtamalization is an ancient process, where corn grain is cooked in a Ca $(OH)_2$ solution, followed by steeping, washing and grinding, to obtain flour and other by-products. During the cooking process, calcium diffusion to into the grain was limited by the presence of pericarp, which is a barrier to ion diffusion. Calcium and water uptake are essential for the formation of amylose networks during the nixtamalization [5, 6].

The composition of whole maize grain flour contained 10.9% moisture, 6.9% protein, 3.9% total lipids, 1.5% ash and 76.9% total carbohydrates. The mineral composition of whole maize grains was 7.00, 2.70, 127.00, 0.30 mg/100g D.B for Ca, Fe, Mg and Cu, respectively [7]. On the other hand, white dent corn contain about 10-15 % water, 1.5-2 % ash, 3.5-4 % fat, 8-10 % protein, 1.5-2.1 % crude fiber, 1.4-2.0 % soluble sugars and 65-70 % starch, the composition can vary depending on genetic and environmental conditions [8].

Phytic acid (PA, inositol hexaphosphate) is the main phosphorus storage form in plants, particularly in the seeds, corresponding to 60–85 % of the total phosphorus content. In maize grains, phytic acid was ranged from 715 to 760 mg/100g [9, 10]. It acts as an antioxidant and shows activity against some diseases, pathologies, supporting action in the diabetes treatment; prevention and treatment of cancer and inhibition of kidney stones, heart disease and other dysfunctions [11, 12]. However, it can act as an antinutritional factor, being capable to complex proteins and certain important nutrients (especially metal ions) related to processes associated with nutrition and vital functions [13]. The nixtamalized corn products are abundant in calcium due to the Ca $(OH)_2$ addition to corn kernels during the cooking step of nixtamalization process. The lime cooking process reduces phytic acid content in raw corn kernel, losses differ 29.9– 36.1%, depending on the processing conditions [14].

Bressani *et al.*[15] studied the processing conditions on phytic acid, calcium, iron and zinc contents of lime-cooked maize. They found a significant dependence of calcium concentration in the lime concentration, cooking and steeping time. Maize is an essential source of various major phytochemicals such as carotenoids, phenolic compounds and phytosterols. However, these chemical compounds are bioactive, naturally present in plants that provide human health benefits and have the potential for reducing the risk of major chronic diseases [16, 17].

Minerals content in maize was found in different levels according to species, varieties and cultivars, including calcium, magnesium, phosphorus, potassium, sodium [18].

Starch is the major component of maize kernels, about 72–73% of the total weight. The maize starch is an important ingredient in the production of foodstuffs and has been widely used as a thickener, stabilizer, colloidal gelling agent, water retention and as an adhesive. It consists of two glucose polymers: amylose, an essentially linear molecule and amylopectin, a branched form [19, 20].

The gelatinization properties of maize starch are influenced by different parameters such as the botanical source, the starch granule size, extraction method, drying process and storage [21]. On heating, water firstly enters the amorphous regions, which expand and transmit disruptive forces into the crystalline regions [22].

Differential scanning calorimetry (DSC) is one of the thermo-analytical techniques widely used to study the thermal behavior of starches. However, the reported results are not consistent and are sometimes controversial because of the complexity of the thermal behavior of starches and differing measurement conditions [23].Only a few mg of material is required to run the analysis. DSC is the most often used thermal analysis method, primarily because of its speed, simplicity and availability [24]. It is mostly used for quantitative analysis [25].The most important parameter in the gelatinization study is the temperature. The properties of the gelatinization are expressed in a thermo curve for DSC. The results are used to determinate the initial temperature (To), the peak temperature (Tp) is the begin of gelatinization, the final temperature (Te), the width of the endothermic peak (ΔT) and the peak high index (PHI), these parameters are used to determinate the homogeneity and uniformity of the starch gelatinization [26, 27].

Maize is consumed across the world in a variety of whole and processed products. Whole-grain maize is consumed boiled or roasted on the cob, canned or frozen sweet corn and as popcorn. So, maize grains can be treated with different preparation methods before processing. After treatment maize can be milled to obtain whole grain flour or fine flower, which used in the processing of foods. On the other hand, these preparations methods often include further processing, such as soaking, fermentation and nixtamalization, which affects the content and bioavailability of several nutrients. Nutritional changes during processing are important to consider when assessing nutrient intake in populations who consume a large proportion of their daily intake as maize or maize products [28, 29].

The objective of this study to investigate the effect of different processing methods, including boiling, soaking, nixtamalization on the chemical composition, phosphorus compounds, polyphenolic compounds, thermal properties of starch by DSC and minerals content (Ca, Mg, Cu, Fe) of white dent maize grains (Variety Single Hybrid Giza 10).

MATERIALS AND METHODS

Materials

Samples: The white dent maize kernels (Variety Single Hybrid Giza 10) used in this research was purchased from the Agricultural Research Center, Giza, Egypt during February season 2017.

Preparation of Maize Samples: White (W) maize kernels were prepared in four different ways. The details of sample preparation are given below:

Untreated Maize Kernels (UM): Untreated white maize (UM) refers to raw kernels as such; the UM sample was ground for 3 min in laboratory mill to obtain whole flour, which contains the germ and the pericarp, in addition to the endosperm. Nothing is separated out when milled. It stored at 4°C until analyzed.

Boiling (BM): Boiling refers to maize kernels which boiled in water (200 g kernels/ 300 ml H_2O) for 10, 20 and 30 min. Boiled white maize (BM) kernels were dried (50°C/24hrs) and then treated in the same way as UM.

Soaking (SM): Soaking refers to maize kernels which soaked in water (200 g kernels/ 300 ml H_2O) for 12, 18 and 24 hours at room temperature (20±4°C). Soaked white maize (SM) kernels were dried (50°C/24hrs) and then treated in the same way as UM.

Nixtamalization (NM): Nixtamalization refers to cooking 200 g of white maize kernels with 400 ml calcium hydroxide solution 1% (in this research, i also used 0.5% and 1.5% $Ca(OH)_2$ solution) for 23 min and then left to steep at room temperature for 16 h according to Figueroa *et al.* [30]. The steep liquid was drained and the maize was rinsed three times with H_2O. Nixtamalized whole white maize (NM) kernels were dried (50°C/24hrs) and then treated in the same way as UM.

Proximate Composition: Moisture, crude protein, crude lipids, crude fiber, ash and starch were determined as described in the AOAC methods [31]. Triplicate determinations were carried out for each sample and the means were reported. The total carbohydrates content was determined by difference, according to Pellet and Sossy [32] as follows: Carbohydrate % = 100 – (Protein % + ash % + lipid % + crude fiber %). The caloric value was calculated using values of 4 k.cal/g for protein,carbohydrates and 9 k.cal/g for fat according to Livesy [33]. The contents of Ca, Fe, Cu and Mg in the studied samples were determined by ICAP6200 (ICP-OES) Inductively Coupled Plasma Emission Spectrometry [34]. Total phosphorus content was determined by spectrophotometer [35] after wet ashing following method described in AOAC [31]. Total phosphorus (TP) = Phytate phosphorus (Pp) + Inorganic phosphorus (Ip).

Total titratable acidity (T.T.A) and pH: T.T.A (ml equivalents of NaOH 0.1N) and pH values of all samples slurry was determined according to the method described by AOAC [31].

Polyphenolic Compounds: The free, bound and total phenolic compounds contents of the samples were determined using modified Folin-Ciocâlteu colorimetric method [36].

Determination of Phytic Acid: The phytic acid was determined by the method described by Kent-Jones and Amos [37] in which the phytic acid is precipitated with an iron-III solution of known iron content and the decrease in iron in the supernatant is taken as a measure of phytate phosphorus content. The phytate was estimated by multiplying the amount of phytate phosphorous by a factor of 3.55 based on the empirical formula $C_6 P_6 O_{24} H_{18}$ [38].

Differential Scanning Calorimetry (DSC): Gelatinization characteristics of the whole maize flour were determined using differential scanning calorimetry (TA-60WS, Shimadzu, Kyoto, Japan). The samples were placed in aluminum hermetic sealed pans with water content 50% and were stabilized at room temperature during 15 minutes, then samples were heated from 40 to 300°C at the rate of 10°C min-1 using an empty pan as reference and a nitrogen environment [27]. For each endothermic peak, the gelatinization transition parameters were measured using DSC software. These values were referred as the onset temperature of gelatinization (To), peak temperature (Tp), end temperature (Te), gelatinization enthalpy (ΔH), the peak high index (PHI) and the range of gelatinization **(ΔT)** which calculated by subtracting To from Te.

Statistical Analysis: The experimental data were subjected to an analysis of variance (ANOVA) for a completely randomized design using a statistical analysis system [39].

RESULTS AND DISCUSSION

Physical Characteristics of Raw White Dent Maize Grains. (Untreated): The physical characteristics of raw white dent maize grains are shown in Table 1. From these data the weight, volume of 1000 grains was 314.41 g, 484.20 mL and the density was1.54 g/mL. The density of dent corn usually ranges between 1.18 to 1.4 g/cm³. Corn with a high amount of hard endosperm generally has high density values, as the structure is tightly packed without the presence of large air cells. Density can be correlated to hardness and kernel texture [40].

Chemical Composition (G/100 G Dry Weight) of White Maize Samples (Whole flour): The moisture content of raw and treated white maize samples (Whole flour) before and after drying in the oven at 50° C/24hrs are shown in Figures 1, 2. It is clear that from Figure 1 that the moisture content was significantly higher in all treated samples as a result of the treatments. The highest value was in the NM0.5% (41.39%) followed by the B30min sample (39.82%) then NM1.0% (38.02%) and the lowest was the B10min sample (25.40%) when compared with the UM sample (10.46%).

Table 1: Physical characteristics of raw white dent maize grains (Untreated)

Sample	Weight 1000 grains	Volume 1000 grains	Seed density
Dent maize	314.41 (g)	484.20 (mL)	1.54 (g/mL)

The percentage of moisture was highly significantly decreased in the treated samples after drying in the oven at 50° C/24hrs, as a result of the drying process, where moisture content ranged from 6.88% to 14.11% as compared to UM 10.46% (Fig. 2).

Moisture is a very important parameter when taking into account the quality of flour and acceptability of flour products. The moisture content should not exceed 15.5% in maize meal flour. In similar studies with wheat flour, moisture content with the range 9-13% was being observed [41, 42]. So our results were within recommended limits.

The chemical composition (On dry basis) of untreated (UM) and treated whole maize flour is presented in Table 2. The UM flour had the highest contents of ash (1.46), oil (4.93) and caloric value (404.25 kcal/100g). It is clear that as a result of boiling, soaking and nixtamalization, there was a significant decrease in the ash and crude lipids values and caloric value, ranging from 1.23-1.40%, 3.04-4.48% and 395.96-403.40kcal/100g, respectively. On the other hand, there were significant

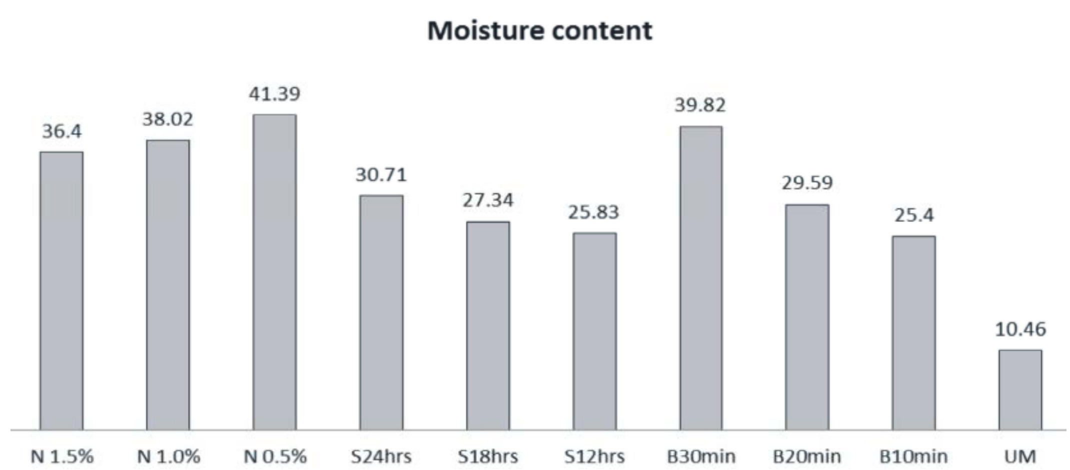

Fig. 1: The moisture content of raw and treated white maize samples (Whole flour) before drying in the oven at 50° C/24hrs.

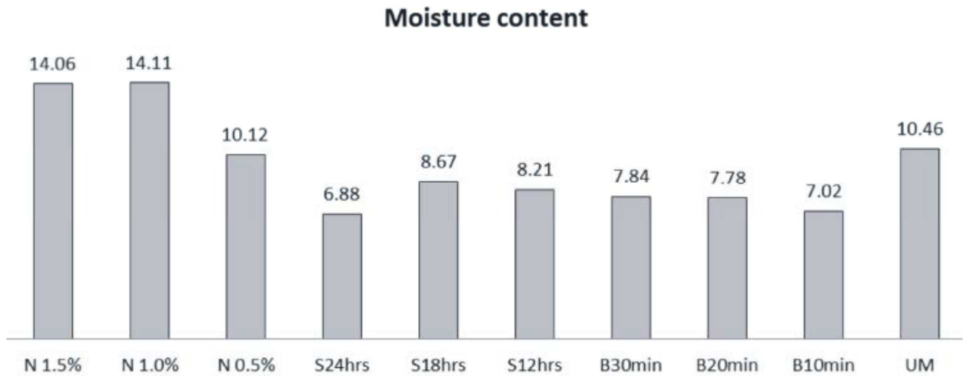

Fig. 2: The moisture content of raw and treated white maize samples (whole flour) after drying in the oven at 50°C/24hrs.

Table 2: Chemical composition (g/100 g dry weight) of white maize samples (Whole flour).

Sample	Ash	Crude lipids	Crude protein	Crude fiber	Total carbohydrates	The caloric value (Kcal/100g)
UM	1.46	4.93	8.75	3.64	81.22	404.25
BM 10 min.	1.40	3.54	9.84	3.56	81.57	397.50
BM 20 min.	1.36	3.40	8.97	2.96	83.31	399.72
BM 30 min.	1.23	4.48	8.09	3.52	82.68	403.40
SM 12 hrs.	1.30	3.32	8.31	3.35	83.72	398.00
SM 18 hrs.	1.28	3.24	8.75	3.46	83.27	397.24
SM 24 hrs.	1.25	3.33	8.97	3.71	82.74	396.81
NM 0.5%.	1.35	3.90	8.09	3.67	82.99	399.42
NM 1.0%.	1.32	3.04	8.31	3.48	83.85	395.96
NM 1.5%.	1.23	4.26	8.31	3.69	82.51	401.62
LSD 0.05	0.043	0.21	0.32	0.23	0.43	1.32

Table 3: The phosphorus fractions and polyphenolic compounds of white maize samples (Whole flour).

Sample	Total phosphorus (Tp)	Phytate phosphorus (Pp)	Inorganic phosphorus (Ip)	Phytate phosphorus as % of total phosphorus	Phytic acid	Polyphenolic compounds (mg/100g) Free	Bound	Total
UM	343.98	205.44	138.54	59.72	729.31	5.37	302.01	307.38
BM 10 min.	320.08	193.88	126.20	60.57	688.27	5.87	256.38	262.25
BM 20 min.	337.53	172.23	165.30	51.03	611.42	8.29	235.03	243.32
BM 30 min.	339.34	151.24	188.10	44.57	536.90	8.51	233.87	242.38
SM 12 hrs.	309.72	174.47	135.25	56.33	619.37	6.31	292.32	298.63
SM 18 hrs.	316.89	129.64	187.25	40.91	460.22	6.50	286.52	293.02
SM 24 hrs.	317.69	94.34	223.35	29.70	334.91	6.68	288.07	294.75
NM 0.5%.	279.83	189.32	90.51	67.66	672.09	7.84	281.76	289.60
NM 1.0%.	281.63	176.74	104.89	62.76	627.43	7.92	244.33	252.25
NM 1.5%.	290.19	150.37	139.82	51.82	533.81	8.20	242.50	250.70
LSD 0.05	1.87	2.36	3.42	2.13	4.12	0.76	2.88	4.16

differences between the control and the treated samples, either increase or decrease in the contents of crude protein, crude fiber and total carbohydrates, which varied between 8.09-9.84%, 2.96-3.71% and 81.22-83.85% for all studied samples, respectively. Our results for chemical composition are in agreement with results previously published by Zilic *et al.* [43].

The good quality flour of maize should have the protein content above 8% dry weight; in addition the ash content is an indication of husks in maize. It also indicates the level of mineral composition in the flour. The maximum recommended limit for ash in flour is 3% [42].

The Phosphorus Fractions and Polyphenolic Compounds: The phosphorus factions in maize samples are illustrated in Table 3. From these data, there were highly significant decreases in the values of total phosphorus (Tp), phytate phosphorus (Pp) and phytic acid in treated maize samples. The values of Tp, Pp (mg/100g) ranged from 279.83 to 339.34, from 94.34 to 193.88 in treated samples when

Table 4: The contents of Ca, Mg, Cu, Fe (mg/100g D.W.), total titratable acidity (T.T.A) and pH values in white maize samples (Whole flour).

Samples	Ca	Mg	Cu	Fe	T.T.A (melequiv. NaOH)	pH values
UM	11.05	60.02	0.26	3.53	4.53	5.59
BM 10 min.	11.78	66.28	0.24	3.37	4.09	5.88
BM 20 min.	11.91	64.94	0.07	2.03	3.92	6.20
BM 30 min.	8.55	66.01	0.13	2.87	2.62	5.75
SM 12 hrs.	11.99	68.35	0.05	3.13	4.01	5.87
SM 18 hrs.	17.06	67.99	0.09	2.30	3.52	5.78
SM 24 hrs.	29.46	68.38	0.01	2.43	3.08	5.89
NM 0.5%.	12.32	63.05	0.06	2.56	2.79	5.76
NM 1.0%.	30.96	67.67	0.03	2.68	2.67	5.93
NM 1.5%.	33.93	63.84	0.05	2.26	2.39	6.23
LSD 0.05	1.23	2.37	0.034	0.14	0.13	0.26

compared with values 343.98 and 205.44 for the UM sample, respectively. Consequently, there was a variance in the values of inorganic phosphorus (Ip), which increased or decreased significantly as a result of the difference in the reduction of Pp due to various treatments, ranging from 90.51 to 223.35 mg/100g when compared to UM 138.54 mg/100g. In general, there is a relationship between the values of Ip and Pp, as their total is equal to Tp, resulting in these differences. The phytic acid content in the treated samples decreased significantly with percentages from 5.63% to 54.08% due to the nature of the treatment itself. The sample SM 24 hrs was the lowest in phytic acid content (332.08 g/100g) when comparing with UM (723.15 mg/100g), which means that soaking for 24 hrs was more efficient in reducing of phytic acid. Soaking can activate endogenous phytase activity in many cereals, which decreases phytic acid; although phytic acid reduces the bioavailability of some nutrients, it also serves as an antioxidant. The phytic acid in maize provides protection to the kernel from the pro-oxidant effects of the metals present and may also prevent damage to DNA and loss of lipids during storage. Therefore, the various thermal treatments, which including boiling, soaking and nixtamalization, have a significant effect in reducing the values of phytic acid in different proportions and this is consistent with previous studies in this field [17, 44, 45].

Table 3 shows the free, bound and total phenolic compounds contents (mg GAE/100g D.W.) in maize samples under study. It was observed that there was a significant decrease in the total and bound phenolic contents of all the treated samples due to boiling, soaking and nixtamalization, with values ranged from 242.38 to 298.63%; from 233.87 to 292.32% when compared with control values 307.38% and 302.01%, respectively. As for the free phenolics, it is clear from the Table 2 that it was increased in the treated samples than the UM sample. As a result of heating during boiling or nixtamalization the free phenolics was higher in B30min (8.51%) and NM1.5% (8.20) samples than UM (5.37%) one. Generally, thermal processing decreases the phenolic content of foods; however, that decline may be due to leaching of water-soluble polyphenols during the treatment [46]. It is clear that there was a breakdown and analysis of total, bound phenolics, which led to an increase in free phenolics as a result of the treatments under study and this, is consistent with some of the previous results [47].

Minerals Composition, T.T.A and pH of Maize Samples: From the data in Table 4 showed that the Ca content was ranged from 8.55 to 33.93 mg/100g (DW) in treated samples comparing to 11.05 mg/100g for UM sample. However, the boiling, soaking, nixtamalization process significantly increases calcium content of maize samples except BM30min it decreased. One study found a highly significant increase in calcium content associated with cooking, soaking and soaking time of maize in lime water. The Mg content in the UM sample was 60.02mg/100g and after the treatments, it was increased to highest content 68.38 mg/100g in SM 24hrs. On the other hand, it was ranged from 63.05 to 68.35 mg/100g in the rest of sample. It is clear that the Mg content is slightly increased as a result of such treatments as well as the breakdown of Mg part associated with the phytic acid in the form of complex and consequently as a result of the decomposition of phytic acid increases Mg [17].

The Cu contents of the studied samples ranging from 0.01 to 0.26 mg/100 g (Table 4). It is clear that Cu content was decreased in the treated samples comparing to Um sample. That was in agreement with report of USDA [7] who reported that whole-grain flour, seem to retain between 60% and 80% of copper as a result of treatment.

The percentage of iron in dry maize grains is 2.7 mg [16]. In this study, the content of iron was 3.53 mg / 100 g in the UM sample; while in the treated samples it significantly decreased in values ranging from 2.26 to 3.37

Table 5: Gelatinization characteristics by DSC thermogram and starch content (g/100 g dry weight) of white maize samples (Whole flour) 50% water in DSC analysis.

Sample	Onset temp. (°C)	Peak temp. (°C)	End temp. (°C)	ΔT (°C)	ΔHP ($J.g^{-1}$)	PHI (%)	Starch
UM	40.98	80.56	140.29	99.31	4.17	10.54	55.81
BM 10 min.	42.37	73.62	142.07	99.70	4.19	13.41	59.60
BM 20 min.	41.67	72.22	136.12	94.45	3.97	13.00	60.13
BM 30 min.	40.98	70.83	130.57	89.59	3.76	12.60	69.83
SM 12 hrs.	42.37	80.56	134.73	92.36	3.88	10.16	57.30
SM 18 hrs.	41.67	77.78	131.96	90.29	3.79	10.50	61.95
SM 24 hrs.	30.56	75.01	129.18	98.62	4.14	9.31	63.25
NM 0.5%.	42.37	77.78	136.85	94.48	3.97	11.21	60.22
NM 1.0%.	42.37	73.62	134.73	92.36	3.88	12.42	62.41
NM 1.5%.	30.56	73.62	134.73	104.17	4.38	10.17	66.48
LSD 0.05	0.96	1.13	1.26	0.86	0.06	0.34	0.75

mg/100 g (Table 4). The boiling in water or lime solution, as well as the soaking in the water, was associated with a significant decrease in the amount of iron, which is consistent with Bressani *et al.* [16] who mentioned such results.

As shown in Table 4, the T.T.A of treated samples was decreased significantly comparing to the UM sample. The content (Melequiv. NaOH) of T.T.A was higher in UM: 4.53 than treated samples with range from 2.39 to 4.09. The pH of the samples ranged from 5.59 to 6.23. It is clear that the pH content was increased as a result of treatments comparing to the UM sample. However, the increase in pH of treated studied samples may be due to lower total titratable acidity.

Thermal Properties (DSC) of Whole Maize Flour Samples: The gelatinization characteristics by DSC and starch content (g/100 g dry weight) of white maize samples (Whole flour) 50% water in DSC are illustrated in Table 5, as well as, the endothermic peaks of samples are shown in Figures 3-12. The starch content of studied samples was ranged from 55.81% to 69.83%. It is clear that the starch content was increased significantly in treated samples (as a result of treatment) than the UM one. The obtained results are in accordance with Zilic *et al.*[2] who reported that the starch (% of dry matter) content of ranged from 54.59% to 69.92% in grain of the analyzed specialty maize hybrids.

The gelatinization temperatures and enthalpies varied significantly between whole maize flours under study. The onset temp (To) was ranged from 30.56 to 42.37°C, while peak temp (Tp) ranging from 70.83 to 80.56°C as compared to 40.98°C and 80.56°C for Um sample, respectively. On the other hand, end temp (Te) was significantly different among the flour samples with higher degrees. Te was highest in BM10min (142.07°C) and the lowest in SM24hrs (129.18°C) comparing to UM (140.29°C). Due to the high Te and low To, this in turn leads to a difference **ΔT** is somewhat large and range from 89.59 to 99.70 °C, which **ΔT**= Te – To. In general, the differences in the higher gelatinization temperatures due to the effect of the treatments used in this study. The higher peak temperatures are because of starch annealing leads to the formation of more ordered starch chains and also because some starch has already gelatinized (as a result of treatment) which increase the temperature [48, 49]. Also, the gelatinization temperature is not an intrinsic property; it depends on the process parameters such as water content and particle size [50].

As shown in DSC Figures 3-12 the enthalpy change (ΔHP) of treated whole flours were different in comparison with untreated sample in the endothermic shapes. The ΔHP content ranging from 3.76 to 4.38 $J.g^{-1}$ for all the studied flours with small significant difference between the treated and Um sample (Table 5). The results indicated that treatments causing a slightly pregelatinizatin in starch molecules. The variations in ΔHP could represent differences in bonding forces between the double helices that form the amylopectin crystallites, which resulted in different alignment of hydrogen bonds within starch molecules [51]. In addition to water content, heating conditions and starch source influence the shape of DSC thermograms of starch–water systems [52]. The peak high index (PHI) of studied samples is calculated dividing the ΔHP multiply 100 with the difference between the Tp and To, similar results finding in a study by Sandhu and Singh [27]. The PHI was ranged from 9.31 to 13.41% for treated samples comparing with 10.54% for the UM (Table 5).

A high transition temperature is the result of a high crystallinity degree, which confers structural stability to starch granules and makes them more resistant to gelatinization. So, the high gelatinization temperatures

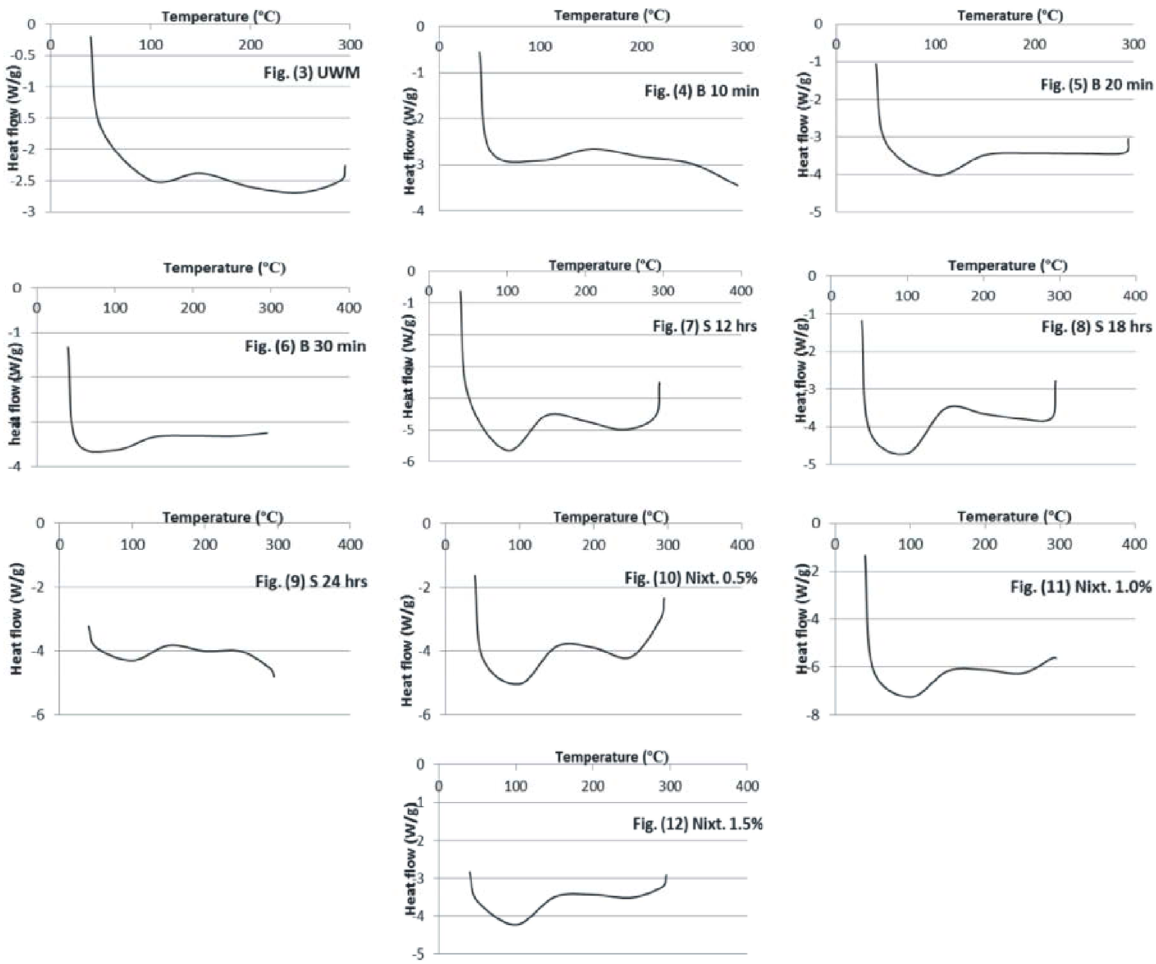

Fig. 3-12: The differential scanning calorimetry (DSC) thermograms of white maize samples (Whole flour).

could be associated with interactions between the corn kernel components (Starch, lipid, calcium and protein), which conferred resistance to the gelatinization process. Overall, as cooking time increased, a more ordered structure was formed [53].

CONCLUSION

From this study it can be concluded that the treatment of corn grains before milling to obtain the whole flour gives better results than untreated grains. The treatments used in the study had an effect on the change in the content of nutrients such as the reduction of phytic acid content when compared with untreated whole flour. Thus, it is better to consumption the whole flour of corn grains than the fine one. On the other hand as whole flour has a good quality, so it is possible to using in bakery products such as toast bread.

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