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Nutritional and Technological Effect of Whole Sorghum (*Sorghum Bicolor* L) Grains Flour as a Supplementation Agent in Bread and Chicken Burger Processing

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Abstract: In this study, two white sorghum (*sorghum bicolor* L) cultivars namely: Dorado and Giza 15 were subjected to soaking treatment for 24 hours then knowing its effect on chemical, minerals composition and phosphorus fractions. Dorado Treated Whole Flour (DTWF) was chosen as a best sample to prepare sweet fermented bread and chicken burger with ratios 10, 20, 30 and 40% from it. Further, the resulting fresh breads were used to determine sensory, physical properties, phosphorus fractions and starch content as well as gelatinization properties by DSC. The obtained data revealed that there were significant ($P<0.05$) differences between flour mixtures and also among the fresh bread samples. The gelatinization enthalpies and temperatures varied significantly ($P<0.05$) between wheat flour, DTWF and flours mixtures. For flours mixtures the Onset Temp (To) was ranged from 30.02 to 45.67°C; Peak Temp (Tp) from 66.08 to 80.13°C; End Temp (Te) from 136.21 to 141.36 as compared to 44.42; 79.12; 155.46°C , 31.68; 74.13; 130.84°C for wheat flour and DTWF sample; respectively. On the other hand, the gelatinization temperatures were significantly ($P<0.05$) different between the bread samples especially Te which found with higher degrees when compared to flours and flours mixtures. The gelatinization temperatures and change of enthalpies varied significantly between stored bread samples. The To was ranged from 30.10 to 38.49°C; Tp 109.01 to 120.17°C; Te 139.55 to 147.22 °C. It is clear that the Te was decreased significantly in bread stored 4 days when compared with the same bread at 0 time of storage. Consequently, the ΔHP was significantly decreased with range 4.43 to 4.70 $J.g^{-1}$ for the stalled bread, which stored for 4 days. The retrograde% of supplemented stored bread was significantly ($P<0.05$) higher ranged from 90.00 to 94.00 when compared to control WF bread with value 88.60%. The consumer acceptability which expressed by total score was highest for burgers containing 10%, 20% supplemented burgers, with values 59.30 and 56.60, respectively, as compared with 61.21 for control (100% chicken breast meat). The best results were obtained for bread and burger samples supplemented with 10% and 20% replacement ratio. The chemical composition of the products was found in reasonable amounts, which confirms the highly nutritional value of these products, as well as, desirable properties that the consumer will accepted them.

Keywords: DSC, Gelatinization, Enthalpy, Bread and Burger

I. INTRODUCTION

As a part of general healthy diet, consumption of whole grains which contains germ, endosperm and bran is associated with reduce the risk of many diseases including diabetes, cancer, coronary heart disease and stroke, with lower all-cause mortality. The whole grains are considered as a main source of carbohydrates, multiple nutrients and dietary fiber. In addition, whole-grain consumption is inversely related to hypertension, diabetes and obesity when compared to refined grains, all of which are negative indicators in total cardiovascular health **(Aune et al., 2016; Gong et al., 2018)**.

On the global level, sorghum (*sorghum bicolor* L. Moench) is ranked fifth of the important cereal crops, after wheat, rice, maize and barley. As it is one of the main sources of energy, vitamins, protein and minerals for millions of poor people in developing countries, especially Asia and Africa. In addition it is used in industrial purposes worldwide for food and feed as a major crop. Sorghum is consumed in the world in various ways ranging from stiff and thin porridge, leavened and unleavened bread, boiled sorghum, baked and steamed product, snack foods, alcoholic and non- alcoholic beverages. Its grains have a chemical composition are follow: moisture 8.10-9.99; ash 0.92-1.75; protein 8.90-11.02; fat 2.30-2.80; crude fiber 1.40-2.70; total carbohydrates 70.65-76.20 and starch 70.00-72.00%. Moreover, minerals content (mg/100g DW) was found with values: P 381.37; K 264.53; Ca 33.09; Fe 7.65 and Zn 5.02 **(Afify et al., 2012; Iranna et al., 2012).** The nutrients components of sorghum grains were found on average about 72.1 g carbohydrates, 12.4 g water, 10.6 g proteins, 6.7 g fibers, and 3.5 g lipids, and 1,377kJ energy for 100 g of the grain. Soaking process has been recommended to enhance the nutritional value and potential functional effects of cereal grains and cereal-based products **(Garzón et al., 2016; Kim et al., 2018)**.

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The myoinositol hexakis dihydrogen phosphate or phytic acid considered as the phosphorous primary storage compound of comprising 1–5% by weight in cereals, legumes and nuts, these amount were variable in plants depending on harvesting techniques and growing conditions. It represented 50–85 % of total phosphorous in plants. Especially cereals and cereal products are rich in phytic acid content. The molecule of phytates has the ability to chelate proteins and digestive enzymes such as trypsin, pepsin, amylase as well as, metal cations, primarily calcium, iron and zinc. The antinutritional compounds such as, phytic acid was reduced by soaking which activate enzyme phytase. Soaking of sorghum for 20 hours in distilled water reduces phytate content by 32.4%**,** which soaking is often used as a pretreatment to facilitated grain processing. Phytate is water soluble, and there for significant phytate reduction can be released when soak water is discarded **(Afify et al., 2011; Ertop and Bektaş 2018).**

The quality of bread is depending on some factors like processing conditions, dough properties and composition**.** Moreover, one of the major factors affecting dough rheological properties is the formation of a gluten matrix. The use of composite flours in breads helps to improve its nutritional quality, utilize indigenously grown cereals, reduce the cost of products and bring in varieties with different texture and flavor. In developing countries like Africa, wheat products such as bread has been an ever- increasing demand. Africa is not major growing region for wheat, but it produces other cereals such as sorghum in large quantities **(Xiong et al., 2019)**.

Thus, whole-grain white sorghum flours can be utilized in a wide variety of food systems, in baking as a partial or complete substitute for wheat flours. **Wu et al., (2018)** have shown that incorporation of white or red sorghum whole grain flour into bread can be enhanced antioxidant activity and the phenolic contents at a 30% supplementation ratio with wheat flour. However, because of the defficiency of gluten, sorghum is not considered as bread making cereal, but addition of 20 to 50% sorghum flour to wheat flour produces good bread. Incorporating sorghum grain or components in foods has been extensively used in flat breads, pita breads to improve food quality and functionality **(Khan et al., 2013; Xiong et al., 2019).**

Starch is stored as granules in the endosperm, which considered as a dominant carbohydrate in sorghum. It ranges from 32.00 to 72.00 g/100 g grain. Sorghum starch consists of mainly amylopectin and amylose. As a result of the high content of resistant starch, slowly digestible starch, strong interactions between starch granules and endosperm proteins, sorghum has the lowest starch digestibility amongst cereal crops (**Barros et al., 2012; Barros et al., 2014)**.

Native starch molecules are insoluble in cold water. When a starch granules is heated in an aqueous suspension above a certain temperature, the granules follow an irreversible order-disorder transition (gelatinization). DSC is the most widely applied technique to measure heat of gelatinization of starches, but comparisons between studies on the extent of phase transitions are sometimes difficult due to considerable variations in experimental conditions, especially water content, heating rate and time. Differential scanning calorimetry (DSC) is a widely-applied technique for many thermal studies in starches during gelatinization that can give the information of transition temperature and enthalpy change of starch (ΔH) (**Schirmer et al., 2015; Wang and Copelend 2013; Wang and Copelend 2015**).

The gelatinization of starch has been generally defined as the disarrangement of molecular orders (hydrogen bonds breaking) within the starch granule showed in irreversible changes in properties such as water uptake, granular swelling, crystallite melting, unwinding of double helices, starch solubilization, loss of birefringence, and viscosity developmen. On heating, water restyle enters the amorphous regions, which expand and transmit disruptive forces into the crystalline regions. These changes are accompanied by swelling of the granules, which under mixing conditions the viscosity was increased before the final breakdown of the granules to form a paste, if the water content of the system is high enough (**BeMiller 2011).**

The main technological changes that occur during bread staling include loss of freshness, loss of crust crispness, increased starch crystallinity, increased crumb firmness, and loss of organoleptic properties. Although the simplest way to evaluate bread staling is the measurement of firmness, analytical tools such as thermal analysis, spectroscopy, and microscopy have been used to understand and control this phenomenon (**Salinas and Puppo 2018**).

The staling of bread is a physico-chemical process that including changes of the matrix both at the molecular and the macroscopic scales. Concerning on these scales, this phenomenon molecularly affects starch crystallinity and retrogradation, decrease in the amount of soluble amylose, redistribution of water between molecules, changes in the gluten network, interactions between gluten protein and starch granules, but macroscopically staling affects crust softening, crumb firmness and flavor deterioration. The change in the amount of retrogradated amylopectin is considered one of reasons for bread crumb staling. Bread firming might be illustrated by a difference in the repartition between the amorphous, crystalline regions and the organization of polymers within the amorphous region of bread crumb **(Curti et al. 2017; Nouri et al. 2017)**.

For a long time, it was believed that amylopectin retrogradation was the only phenomenon responsible for increasing bread firmness during storage. However, some authors have reported that bread staling is not only due to amylopectin retrogradation. Some types of reactions in foods during storage occur due to changes in physical properties, including protein gelation, starch gelatinization and textural changes during cooking and storage. These reactions exhibit hardening/softening kinetics (**Ding et al., 2019**).

The amylose and amylopectin molecules in gelatinized starch on cooling and storage can realign into more ordered structures, in a process referred to as retrogradation. The term retrogradation was first used to describe the observation of starch regaining crystallinity following gelatinization. Retrogradation of starch results in considerable changes such as increase in viscosity, opacity and gel firmness, phase separation between polymer and water (syneresis). These changes are of great interest in food science and technology, since they significantly influence the quality, acceptability, nutrition, and shelf-life of starch-rich foods **(Hoover et al., 2010)**.

Short-term storage leads to retrogradation of basically amylose, whereas recrystallization of amylopectin side chains is much slower. Depending on the ability of branching chains to form associations, the amylopectin was retrograded over a period hours to days and amylose over minutes to hours which used to determine the initial hardness of a starch gel. On the other hand, the long-term development of crystallinity and gel structure of treated starch is determined by retrogradation of amylopectin. In treated foods the retrogradation of amylose is contribute to properties relating to stickiness, digestibility and ability to absorb water, whereas the retrogradation amylopectin is probably a more important determinant in the staling of cakes and bread **(Delcour and Hoseney 2010).**

The presence of lipids during hydrothermal treatments can decrease the swelling capacity of the starch granules, and complex formation has been shown in many studies to increase gelatinization temperature, reduce gel rigidity and retard retrogradation. Starch–lipid complexes with monoglycerides containing longer chain fatty acids are more stable and display higher dissociation and melting temperatures than their equivalents with shorter chain lengths **(Pareyt et al., 2011; Putaux et al., 2011; Obiro et al., 2012).**

Starch retrogradation is a temperature and time-dependent phenomenon, which involves reassociation of starch component molecules into a partially crystalline, ordered structure. The crystallization of starch biopolymer is associated to water supplied mainly from the surrounding matrix namely gluten network and starchy matrix contained in the baked crumb. When amylopectine retrogrades (recrystallisation), water is trapped in the crystalline zones; this water switches from free to bound water and enters in the category of non freezable water. Therefore, water is an important factor which interacts with the retrogradation. Other factors were found to influence this phenomenon, namely storage conditions (time and temperature) and heating rate (**Le Bail et al., 2009**). Moreover, it was demonstrated that in starch gels, the retrogradation depends on the final temperature reached during gelatinization: the higher is the degree of gelatinization, the more retrogradation will occur. It has been established that during baking of bread dough (for which a relative excess of water if present), starch granules gelatinize and swell. The leaching of amylose polymer occurs once swelling starts and is continuing for prolonged thermal treatment. The leached amylose during baking forms a gel around the ghosts of starch granules which contributes to the firmness of the bread matrix **(Le-Bail et al., 2009; Le-Bail et al., 2012).**

Recently, in food production the applications of supplemented materials become essential. It is possible to change the physical, chemical and organoleptic properties of various products at will with the addition of certain food processing aids. Various food supplementations are used both in red and chicken meat production. Meat products have influenced markedly on their texture by supplementation as it contain high levels of myofibrillar proteins **(Uran and Yilmaz 2018)**. The growing interest with human health, improved coordination of agroindustrial chain of broiler chicken, appearance of new products and replacement of red meat considered as main factors influence on the consumption of chicken meat **(Tonollo and Palezi 2016; Santos et al., 2019)**. In burger production, the replacement of red meat by chicken is becoming more popular as a result of low fat content and no religious or cultural constraints to the consumption of poultry**.** Poultry products such as sausages, frankfurters and burger contained about 0 to 20% fat, 60 to 80% water and 17 to 20% protein. Many efforts have been made to improve the quality and stability of burgers because consumer demand for fast food has been increasing rapidly in recent years (**Mikhail et al., 2014; Al-Juhaimi et al., 2017).**

The aim of the study is to investigate the effect of soaking for 42 hours on the chemical and mineral composition, as well as phosphorus fractions of two varieties of white sorghum Dorado and Giza 15. The best sample in terms of nutritional components was used to prepare sweet fermented bread with ratio of 10-40% of DTWF, flours, flour mixtures and fresh bread was thermally analysis by DSC, as well as the sensory properties and chemical composition of fresh bread were determined. In addition, the staling and retrogradation in the bread after 4 days of storage at room temperature was measured by DSC. Also, the chicken burger was prepared with 10-40% ratio of the DTWF sample, then estimating the physical properties and chemical composition of the resulting burger.

II. MATERIALS AND METHODS

Materials

The white varieties of sorghum grains: Dorado and Giza 15 used in this study were purchased from the Agricultural Research Center, Giza, Egypt during March season 2018.

Preparation of sorghum samples

White sorghum grains were prepared in two different ways. The details of sample preparation are given below:

- **Raw sorghum grains:** Raw Dorado and raw Giza 15 sorghum grains refer to raw grains as such; the samples were ground for 3 min in laboratory mill to obtain whole flour and stored at 4°C until analyzed.
- **Treated sorghum grains:** Sorghum grains were cleaned, sorted, soaked in distilled water (1: 5 w/v) for 24 h, removed from water, washed and dried in an electrical oven at 60°C for 2 hrs. Treated Dorado sorghum and treated Giza

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15 grains were ground for 3 min in laboratory mill to obtain whole flour and stored at 4°C until analyzed. The names of samples were DTWF (Dorado treated whole flour) and GTWF (Giza 15 treated whole flour).
The proximate composition of materials used in preparing chicken burger and sweet fermented bread are shown in Table (1).

Table (1): Chemical composition contents (g/100g D.W)* of chicken breast, wheat flour used in processing of chicken burger and sweet fermented bread.

Materials	**Moisture**	**Protein***	**Oil***	**Ash***	**Crude fiber***	**Total carbohydrates***	**Energy* (Kcal/100 g)**
Chicken breast meat	72.87	65.38	10.57	6.94	1.38	15.73	419.57
Wheat flour (72% extraction)	12.12	12.85	1.57	0.63	0.82	84.13	402.05

Methods

Proximate chemical composition: Crude protein, crude fiber, moisture, crude oil, ash and starch were determined as described in the **A.O.A.C** (**2000**). Total carbohydrates were calculated according to method reported by **Pellet and Sossy (1970)**. The values: 9 k.cal/g for oil, 4 k.cal/g for carbohydrates and protein were used to calculate the caloric value or energy (**Livesy 1995**). The K, Ca, Mg, Fe, Cu and Zn contents in sorghum samples were analyzed by apparatus iCAP6200: Inductively Coupled Plasma Emission Spectrometry (ICP-OES) (**Isaac and Johnson 1985**).

Phytic acid determination: The phytic acid determination was done as the phytate ion was precipitated as known iron amount with an iron-III solution and phytate phosphorus content was measured as the decrease in iron in the supernatant. The phytic acid was calculated by multiplying the content of phytate phosphorous by a factor of 3.55 based on the basic formula $C_6 P_6 O_{24} H_{18}$ **(Wheeler and Ferrel 1971).** Total phosphorus and phytate phosphorus contents were determined by spectrophotometer **(Jackson 1967)** after wet ashing as described in **AOAC (2000)** method**.** TP (total phosphorus) = Pp (phytate phosphorus) + Ip (inorganic phosphorus).

DSC (Differential Scanning Calorimetry): Thermal properties of starch or gelatinization transition of the studied samples were estimated using DSC (TA-60WS, Shimadzu, Kyoto, Japan). A known weight of sample was putted in aluminum hermetic sealed pans with water content 50%, samples were heated to 300◦C at the rate of 10◦C per minute using an empty pan as reference and a nitrogen environment after stabilization the sample at room temperature during 15 minutes **(Sandhu and Singh 2007).** The gelatinization transition parameters were measured using DSC software for each endothermic peak. These values were referred as To (onset temperature of gelatinization), Tp (peak temperature), Te (end temperature), ΔH (gelatinization enthalpy), PHI (peak high index) and Δ**T** (range of gelatinization**)** which calculated as follow: ΔT = Te - To. **Retrograde %** of studied bread stored for 4 days at room temperature (25±4ºC) was determined by DSC, which calculate the gelatinization transition parameters as mentioned above.
The retrograde % = $[\Delta HP_{(\textbf{at 4days})} / \Delta HP_{(\textbf{at 0 time})}] \text{ X } 100$

Processing, evaluation and physical properties of sweet fermented pan bread: Sweet fermented pan bread was supplemented with 10%, 20%, 30% and 40% Dorado treated whole flour (DTWF). The basic formula was: sugar, water, wheat flour, fresh whole egg, vegetable oil, baking powder, dried yeast and salt with percentage illustrated in Table (2). The sweet fermented bread was processed **(Bathie 2000)** as follows**:** water and flour mixing together then the other ingredients were added, kneading to make dough, which placed in the pans, fermented and baked. The bread surface would be dark brown at the end of baking. The bread must be cooled after baking then evaluated. The sensory characteristics of bread samples are odor (10), color of crust (10), graining of crumb (10), color of crumb (10), taste (10), texture (10) and total score (60). The studied bread was scored by the judges from the staff of Food science and Technology department, Faculty of Agriculture, Assiut University, as described by **AACC (2000)** method.

Table (2): Formation of sweet fermented bread supplemented whole sorghum flour.

Ingredients	**Control**	**10%**	**20%**	**30%**	**40%**
Wheat flour 72% (g)	113.75	102.375	91.00	65.875	54.50
Whole sorghum flour (g)	---	11.375	22.75	34.125	45.50
Sugar (g)	28.38	28.38	28.38	28.38	28.38
Water (ml)	27.50	27.50	27.50	27.50	27.50
Fresh whole egg (g)	22.50	22.50	22.50	22.50	22.50
Vegetable oil (ml)	21.12	21.12	21.12	21.12	21.12
Baking powder (g)	3.38	3.38	3.38	3.38	3.38
Dried yeast	3.38	3.38	3.38	3.38	3.38
Salt (g)	1.14	1.14	1.14	1.14	1.14

After baking the average weight (g) of bread was recorded within two hours, while the clover seeds displacement method was used to estimate the volume (cm3). Specific volume (cm^3/g) was calculated as follow: Specific loaf volume (cm^3/g) = Volume (cm3)/Weight (g) (**AACC 2000**).

Processing, evaluation and physical properties of Chicken Burger

Burger of chicken was prepared as described by **Mikhail et al., (2014)** with the formula presented in Table (3). The supplemented burgers processed by replacing the chicken meat with 10%, 20%, 30% and 40% DTWF**.** The burger ingredients of formulations were blended in Braun Cutter Machine and then formed into burger.

Table (3): Formulation of chicken burger containing whole sorghum flour.

Ingredients (g)	**Control**	**10%**	**20%**	**30%**	**40%**
Minced chicken breast meat	437.50	393.75	350	306.25	262.50
Whole sorghum flour	---	43.75	87.50	131.25	175
Fresh onion	50	50	50	50	50
Salt	7.50	7.50	7.50	7.50	7.50
Black pepper	2.50	2.50	2.50	2.50	2.50
Allspice	2.5	2.50	2.50	2.50	2.50

Chicken burger samples were cooked, then shrinkage, cooking yield and cooking loss were determined and calculated according to the following equations as described by **AMSA (1995)**:

$$\textbf{Shrinkage (\%)} = \frac{\textbf{(raw thickness-cooked thickness) + (raw diameter- cooked diameter)} \times 100}{\textbf{raw thickness + raw diameter}}$$

$$\textbf{Cooking yield (\%)} = \textbf{(cooked weight/ raw weight)} \times \textbf{100.}$$

$$\textbf{Cooking loss} = \textbf{[(raw sample weight – cooked sample weight)} \div \textbf{raw sample weight]} \times \textbf{100.}$$

The sensory characteristics of cooked burger samples **(AMSA 1995)** are tenderness (10), odor (10), texture (10), taste (10), appearance (10), color (10) and overall acceptability (10), which presented to the judges from the staff of Food science and Technology department, Faculty of Agriculture, Assiut University, who were asked to assigning a score for evaluation the burger.

Statistical Analysis: A statistical analysis of variance (ANOVA) system for a completely randomized design was used to analysis the experimental data (**SAS, 2000**).

III. RESULTS AND DISCUSSION

Chemical composition and minerals contents of whole flours

The moisture content in the studied samples was ranging from 7.01 to 10.21%. As shown in Table (4) the contents of protein, crude fiber and total carbohydrates were slightly increased in treated whole flours when compared with raw flours. On the other hand, the oil content was decreased significantly in treated flours. For the caloric value, the contents were similar, ranging from 400.67 to 401.45 Kcal/100g in the studied samples. As a result of closer values of oil, protein & carbohydrates, the energy was similar. It could be noticed that the differences in the contents of constituents due to the cultivars, used treatment (soaking and heating), which led to the presence of these variations, both decrease or increase.

Table (4): Chemical composition (% DW)* and minerals (mg/100g DW) contents of sorghum samples.

Analysis	**Samples**						**LSD 0.05**
	Dorado		**Mean**	**Giza 15**		**Mean**	
	RWF	**TWF**		**RWF**	**TWF**		
Moisture	10.21	7.01	8.61	10.04	7.03	8.54	0.23
Ash*	1.63	1.42	1.53	1.49	1.27	1.38	2.31
Protein*	9.06	9.11	9.09	8.91	8.96	8.94	0.14
Oil*	3.53	3.29	3.41	3.49	3.23	3.36	0.11
Crude fiber*	2.42	2.49	2.46	2.57	2.60	2.59	0.11
Carbohydrates*	83.36	83.69	83.53	83.54	83.94	83.74	0.21
Energy* (Kcal/100 g)	401.45	400.81	401.13	401.21	400.67	400.94	0.16
K	286.32	274.03	280.18	280.10	270.36	275.23	4.15
Ca	24.50	16.98	20.74	28.24	19.12	23.68	2.53

Mg	178.23	174.68	176.46	180.67	175.24	177.96	1.45
Fe	9.74	8.82	9.28	8.69	7.08	7.89	1.18
Cu	1.23	1.20	1.22	1.36	1.32	1.34	0.09
Zn	5.63	5.18	5.41	5.21	4.85	5.03	0.29

RWF: raw whole flour. TWF: treated whole flour

As illustrated in Table (4) the results revealed that there is a significant ($p<0.05$) differences between RWF and TWF in minerals contents (mg/100g DW), which the K, Mg were the highest mineral in studied cultivars both RWF and TWF. The values of K were: 286.32, 280.10 in RWF; 274.03, 270.36 in TWF for Dorado and Giza 15 cultivars, respectively, while Mg content ranged from 174.68 to 180.67 mg/100g DW for the studied flours. The contents (mg/100g DW) of Ca; Fe was decreased from 24.50, 28.24; 9.74, 8.69 in RWF to 16.98, 19.12; 8.82, 7.08 in TWF of the Dorado and Giza 15 cultivars, respectively, while the contents of Zn, Cu in the flours samples were found with closer values ranging from 4.85-5.63; 1.20-1.36 mg/100g DW, respectively. From the above mentioned data the soaking then heating of RWF have a decreasing different effect on minerals under study except Zn, Cu which did not change like K, Mg, Ca and Fe. Our data are in agreement with **Afify et al., (2012)** who reported the decreasing in the nutrients after soaking treatment might be as a result to leaching minerals and soluble nitrogen and some into soaked solution.

The phosphorus fractions of whole flours: The phosphorus fractions contents (mg/100g D.W.) of raw and treated whole flours samples are shown in Table (5). The contents (mg/100g DW) of total phosphorus (Tp); phytate phosphorus (Pp); phytic acid were significantly ($p<0.05$) decreased from 364.23, 358.21; 191.61, 198.11; 680.22, 703.29 in RWF to 329.41, 321.58; 86.32, 90.54; 306.44, 321.42 in TWF in Dorado and Giza 15 cultivars, respectively, as affected by used treatment. Consequently, the inorganic phosphorus was significantly ($p<0.05$) increased in TWF as compared with RWF. The DTWF sample was lower in phytic acid content (306.44 mg/100g) when comparing with the raw one, which means that soaking for 24 hrs was more efficient in the phytic acid reduction. In many cereals the endogenous phytase can be activated by soaking, which decreases phytic acid. The phytic acid in sorghum grains serves as an antioxidant which protects the kernel from the pro-oxidant effects of the present metals, lowering the loss of lipids during storage and may also prevent damage to DNA. So, many thermal treatments including soaking could be reducing the phytic acid content in different proportions and this is in accordance with previous studies **(Wu et al., 2009; Gupta et al., 2015).**

Table (5): The phosphorus fractions (mg/100g D.W.) contents of sorghum samples.

Analysis	**Samples**						**LSD 0.05**
	Dorado		**Mean**	**Giza 15**		**Mean**	
	RWF	**TWF**		**RWF**	**TWF**		
Total phosphorus (Tp)	364.23	329.41	346.82	358.21	321.58	339.89	5.72
Inorganic phosphorus (Ip)	172.62	243.09	207.85	160.10	231.04	195.57	9.99
Phytate phosphorus (Pp)	191.61	86.32	138.96	198.11	90.54	144.32	4.47
Pp as % of Tp	52.61	26.20	39.40	55.31	28.16	41.73	1.95
Phytic acid	680.22	306.44	493.33	703.29	321.42	512.35	15.85

RWF: raw whole flour. TWF: treated whole flour

Sensory properties and physical evaluation of sweet fermented bread: The sensory properties and physical evaluation of the sweet fermented bread as affected by the supplementation of 10%, 20%, 30% and 40% of Dorado treated whole flour (DTWF) are illustrated in Table (6), Fig. (2). The results revealed that supplemented bread with 10, 20% DTWF recorded the best scores among all fortified breads. On the other hand, taste, texture, crust color, crumb properties scores for fortified breads were significantly ($P<0.05$) different comparing with control bread. As a result of incorporation DTWF in sweet bread the color become darker and crumb graining was less porous compared to the control in the case of bread supplemented with 20%, 30%, 40% DTWF (Fig. 2).

Table (6): Sensory properties and physical evaluation of sweet fermented bread processed from wheat flour (WF) and its blends with Dorado treated whole flour (DTWF).

Bread sample	**Crust color**	**Crumb**		**Texture**	**Taste**	**Odor**	**Total score**	**Physical evaluation**		
		Color	**Graining**					**Volume**	**Weight**	**Specific volume**
	(10)	**(10)**	**(10)**	**(10)**	**(10)**	**(10)**	**(60)**	**(ml)**	**(g)**	**(ml/g)**
WF100% (Control)	9.23	9.13	8.63	8.95	8.99	8.61	53.54	613.00	184.67	3.32
90% WF + 10% DTWF	8.53	8.53	8.30	8.30	8.40	8.40	50.46	600.00	188.96	3.18
80% WF + 20% DTWF	8.05	8.30	8.20	8.20	8.05	8.05	48.85	570.00	190.38	2.99
70% WF + 30% DTWF	7.00	6.85	6.85	7.00	7.00	7.00	41.70	550.00	195.84	2.81
60% WF + 40% DTWF	6.85	6.50	6.50	6.85	6.85	6.50	40.05	529.00	199.01	2.66

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LSD 0.05	0.20	0.14	0.08	0.14	0.15	0.08	0.13	0.69	4.45	0.14

The loaf weight, volume and specific volume of studied bread samples are shown in Table (6). The loaf weight was increased in all supplemented breads with range from 188.96 to 199.01 as compared with 184.67 g for control. On the other hand, the specific volume, loaf volume of supplemented bread with added ratios was lower as compared with wheat flour 100% bread (Fig. 1). These results are similar with those obtained by **Mettler and Seibel (1993)** who illustrated that the decrease in volume caused by dilution of gluten but the increase in loaf weight causing by high water retention.

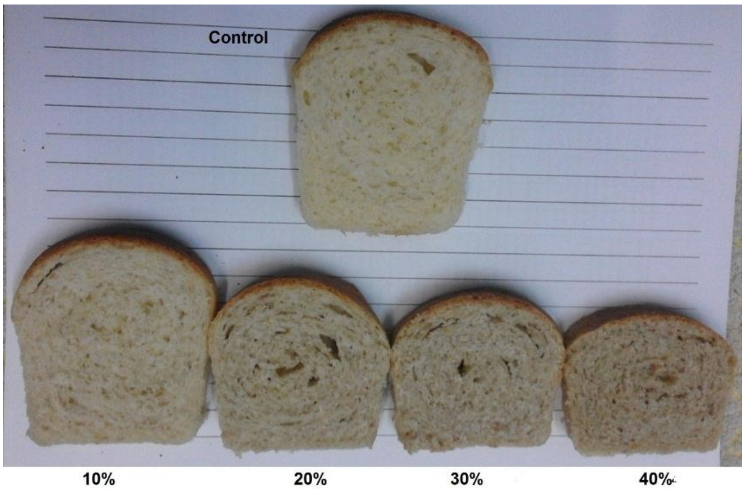

Fig. (1): Showing the sweet fermented bread processed from wheat flour (WF) and its blends with Dorado treated whole flour (DTWF).

Chemical composition and phosphorus fractions of sweet fermented bread: The chemical composition of sweet fermented bread samples are shown in Table (7). The moisture content of studied bread was ranged from 24.25 to 26.46%. The ash content was found in similar values for all breads ranged from 1.11 to 1.19%. The oil, protein and energy contents was significantly ($P<0.05$) decreased in the supplemented bread with DTWF as compared with control but in the same trend the crude fiber and total carbohydrates were increased. The supplemented bread had a lower caloric value ranging from 390.60 to 432.90 comparing with 435.41 Kcal/100 g DW for control bread. These differences in chemical composition, whether increased or decreased, are due to the difference of these components in wheat flour and DTWF.

Table (7): Chemical composition (% D.W.)* of sweet fermented bread processed from wheat flour (WF) and its blends with Dorado treated whole flour (DTWF).

Bread samples	**Moisture**	**Ash***	**Oil***	**Protein***	**Crude fiber***	**Total carbohydrates***	**Energy* (Kcal/100g)**
WF100% (Control)	26.46	1.11	8.45	10.19	0.60	79.65	435.41
90% WF + 10% DTWF	25.11	1.12	8.02	10.10	0.68	80.08	432.90
80% WF + 20% DTWF	24.86	1.13	7.88	10.02	0.80	80.17	431.68
70% WF + 30% DTWF	24.25	1.12	7.35	9.96	1.01	80.56	428.23
60% WF + 40% DTWF	25.68	1.19	6.96	9.93	1.16	80.76	390.60
LSD 0.05	0.12	0.05	0.19	0.07	0.14	0.06	0.26

The phosphorus fractions contents in bread samples are illustrated in Table (8). From these data, there were significant increases in the values of Tp, Pp and phytic acid in DTWF breads with increment the supplementation ratio. For Tp, Pp their contents (mg/100g DW) were significantly ($P<0.05$) higher, ranging from 173.31-206.01, 76.74 -90.67, in DTWF bread samples when compared to 159.56 and 87.63 for control bread, respectively (Table 8). This increase is because of the rise of these values in the DTWF and consequently rises gradually in the resulting bread with increment the supplementation ratio. Also, the Ip content was increased significantly ($P<0.05$) ranging from 96.57 to 115.34 when compared to 87.63 mg/100g DW. The proportions of Pp in studied breads as a proportion of Tp were ranged from 42.90 to 45.08%. Similarly, for the phytic acid, there was a significant ($P<0.05$) increase in DTWF breads with contents (mg/100g D.W) ranging from 272.43 to 321.88 compared to 255.35for the bread produced from wheat flour (control). The phytic acid in DTWF may be decomposed after soaking, so phytic acid would be released as a result of softening and broking the cellular wall. The obtained results are in agreement with **Lopez et al., (2001) and Penella et al., (2008)** who reported: the decomposition of phytic acid (varies from 13 to 100%) during fermentation, baking process depends on some factors such as the activity of phytase in flour, acidity of flour, yeast and bread type.

Table (8): The phosphorus fractions (mg/100g DW) contents of sweet fermented bread samples.

Analysis	**Control WF**	**WF 90% + DTWF 10%**	**WF 80% + DTWF 20%**	**WF 70% + DTWF 30%**	**WF 60% + DTWF 40%**	**LSD 0.05**
Total phosphorus (Tp)	159.56	173.31	180.34	194.08	206.01	2.36
Inorganic phosphorus (Ip)	87.63	96.57	102.97	109.64	115.34	0.21
Phytate phosphorus (Pp)	71.93	76.74	77.37	84.44	90.67	0.05
Pp as % of Tp	45.08	44.28	42.90	43.51	44.01	0.05
Phytic acid	255.35	272.43	274.66	299.76	321.88	0.07

DTWF: Dorado treated whole flour.

Thermal properties of flours, flours mixtures and sweet fermented bread by DSC: The gelatinization properties by DSC of flours, flours mixtures and sweet fermented bread are presented in Table (9). The gelatinization enthalpies and temperatures varied significantly ($P<0.05$) between wheat flour, DTWF and flours mixtures. For flours mixtures the onset temp (To) was ranged from 30.02 to 45.67°C; peak temp (Tp) from 66.08 to 80.13°C; end temp (Te) from 136.21 to 141.36 as compared to 44.42; 79.12; 155.46°C , 31.68; 74.13; 130.84°C for wheat flour and DTWF sample, respectively. On the other hand, the gelatinization temperatures were significantly ($P<0.05$) different among the bread samples especially Te which found with higher degrees when compared to flours and flours mixtures. The To was ranged from 30.98 to 40.67°C; Tp from 120.11 to 128.65°C; Te from 149.27 to 159.30°C in supplemented breads with DTWF as compared to 42.03; 130.42 and 161.03°C for wheat flour bread (control) sample, respectively.

Table (9): Thermal characteristics by DSC, starch content of flours, flours mixtures, fresh sweet fermented bread samples from wheat flour (72% extraction) and whole treated sorghum flour (50% water in DSC).

Sample		**Onset temp. (°C)**	**ΔHTo ($J.g^{-1}$)**	**Peak temp. (°C)**	**ΔHTp ($J.g^{-1}$)**	**End temp. (°C)**	**ΔHTe ($J.g^{-1}$)**	**ΔHP ($J.g^{-1}$)**	**PHI (%)**
Wheat flour (72%)		44.42	1.87	79.12	3.23	155.46	6.53	4.66	13.44
DTWF		31.68	1.33	74.13	3.11	130.84	5.50	4.17	9.82
Flours mixtures	WF 90% + DTWF 10%	40.24	1.69	80.13	3.37	140.20	5.89	4.20	10.53
	WF 80% + DTWF 20%	45.67	1.92	79.65	3.35	141.36	5.94	4.02	11.83
	WF 70% + DTWF 30%	32.14	1.35	70.45	2.96	136.21	5.72	4.37	11.41
	WF 60% + DTWF 40%	30.02	1.26	66.08	2.78	139.60	5.86	4.60	12.76
Bread samples	Control WF	42.03	1.77	130.42	5.48	161.03	6.76	5.00	5.66
	WF 90% + DTWF 10%	39.35	1.65	128.65	5.40	159.30	6.69	5.04	5.64
	WF 80% + DTWF 20%	40.01	1.68	126.57	5.32	157.62	6.62	4.94	5.71
	WF 70% + DTWF 30%	30.98	1.30	120.11	5.05	149.27	6.27	4.97	5.58
	WF 60% + DTWF 40%	40.67	1.71	127.31	5.35	155.02	6.51	4.80	5.54
R LSD 0.05		0.06	0.07	0.05	0.15	0.12	2.09	0.29	0.12

DTWF: Dorado treated whole flour

Generally, the higher gelatinization temperatures of samples under study because of using whole flour not pure starch, so many of reactions could be happen with other constituents in DSC system in addition particle size and water content have a direct effect as a gelatinization temperature did not consider an intrinsic property. On the other hand, the Tp was found in higher degrees because of more ordered starch was formed by starch annealing, also as a result of treatment (soaking, heating, bread making), some starch granules are already gelatinized and consequently the temperature was increased. Our data were in accordance with **Sitanggang et al., (2018)** who confirmed the higher gelatinization temperature for sorghum starch. As shown in Table (9) the change in enthalpy (ΔH) of flours mixtures were significantly ($P<0.05$) different in comparison with bread samples. The ΔHP content of flour mixtures was ranged from 4.02 to 4.60 **$J.g^{-1}$** with small significant ($P<0.05$) difference compared to 4.66; 4.17 for wheat flour and DTWF sample, respectively. For bread samples ΔHP was increased with range 4.80-5.04 **$J.g^{-1}$** when compared to flour mixtures. The PHI (peak high index) which depends on ΔHP content was decreased in bread samples with range 5.54-5.71% as compared with flour mixtures ranging 10.53-12.76%, 13.44% wheat flour and 9.82% for DTWF (Table 9). These differences in ΔHP indicated that a variation alignment of hydrogen bonds into starch molecules resulted from formation the amylopectin crystallites as represented by bonding forces within the double helices, as well as, the effect of starch source, heating conditions and water content in DSC thermograms. As the gelatinization of sorghum starch is higher it release a larger thermal energy as a result of needing a longer cooking time, which due to formation a strong disulfide bonds cross-links between sorghum protein (kafirin) and starch (**Wang and Les Copeland 2013**; **Sitanggang et al., 2018**).

Total starch content (g/100g DW) of the flours mixtures ranged from 73.69–76.34% comparing with 78.26, 70.03% for wheat flour and DTWF, respectively (Fig. 2). Statistical analysis showed that a significant ($P<0.05$) differences was existed between the DTWF and the flours mixtures. Generally, the total starch content of the flour blends were significantly ($P<0.05$) higher than DTWF.

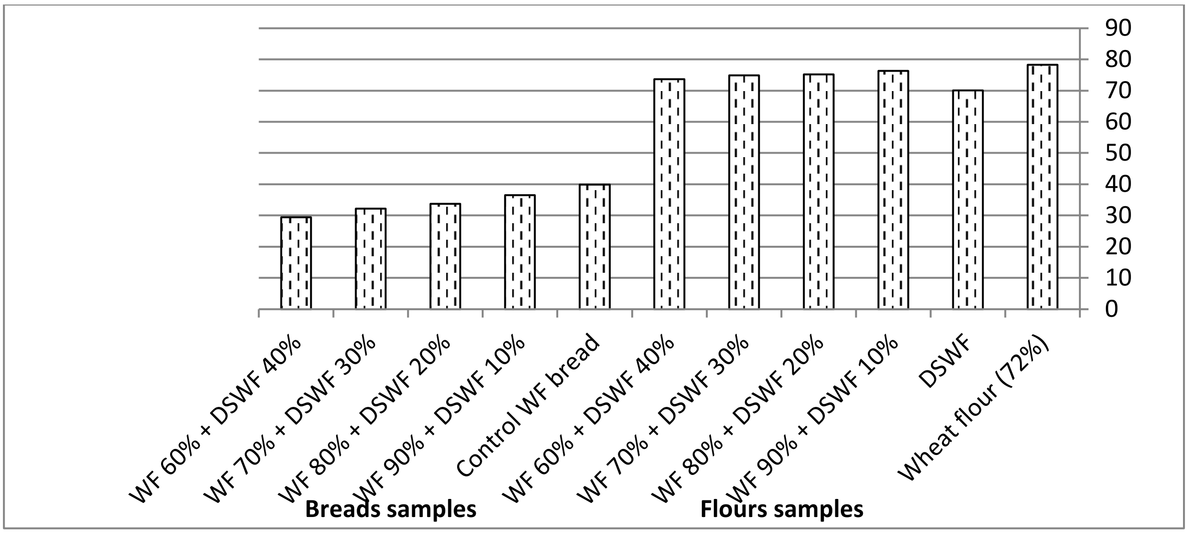

Fig. (2): Showing the total starch content of flours and fresh breads samples

This is because of wheat flour is high in starch. On the other hand, total starch content was ranged from 29.47 to 39.88 in the studied breads, which the wheat flour 100% bread has the highest total starch content (39.88%). So, starch content was generally decreased, as ratio of DTWF increased in their bread samples. This in accordance with **Kiin-Kabari and Giami (2015)** who noticed a significant decrease in total starch with an increase in the banana composite flour amounts.

Thermal characteristics by DSC thermogram of stored sweet fermented bread: Staling is responsible for a number of changes happened in bakery products during the normal storage, which the flour starch is considered as a reason for reactions of staling. DSC is considered one of the quantitative measurements choice for precisely determine the gelatinization properties, which measures the absorbed or released heat or energy during gelatinization by the starch–water systems. The thermograms of starch–water systems can be influenced by some factors such as moisture equilibration time prior to heating, heating rate, water content and the DSC pans types **(Patel and Seetharaman 2010; Wang and Les Copeland 2013)**. Thermal characteristics by DSC thermogram of sweet fermented bread (at 4 days storage at **25±4ºC** supplemented with DTWF are illustrated in Table (10). The gelatinization temperatures and change of enthalpies varied significantly between stored bread samples. The To was ranged from 30.10 to 38.49°C; Tp 109.01 to 120.17°C; Te 139.55 to 147.22 °C. It is clear that the Te was decreased significantly in bread stored 4 days when compared with the same bread at 0 time of storage. Consequently, the ΔHP was significantly decreased with range 4.43 to 4.70 J.g^{-1} for the stalled bread, which stored for 4 days.

Table (10): Thermal characteristics by DSC of sweet fermented bread (at 4 days storage at 25 ± 4ºC) samples from wheat flour (72% extraction) and Dorado treated whole flour (50% water in DSC).

Sample	**Onset temp. (°C)**	**ΔHTo (J.g^{-1})**	**Peak temp. (°C)**	**ΔHTp (J.g^{-1})**	**End temp. (°C)**	**ΔHTe (J.g^{-1})**	**ΔHP (J.g^{-1})**	**PHI (%)**	**Retrograde %**
Control WF	38.20	1.60	120.17	5.05	143.52	6.03	4.43	5.40	88.60
WF 90% + DTWF 10%	35.11	1.48	114.29	4.80	147.22	6.18	4.70	5.94	93.25
WF 80% + DTWF 20%	38.49	1.62	115.83	4.87	145.66	6.12	4.50	5.81	91.09
WF 70% + DTWF 30%	30.10	1.26	109.01	4.58	140.08	5.88	4.62	5.85	92.96
WF 60% + DTWF 40%	31.17	1.31	112.08	4.71	139.55	5.86	4.55	5.62	94.79
LSD 0.05	0.56	0.09	0.03	0.06	0.04	0.06	0.34	0.05	0.16

WF: wheat flour. DTWF: Dorado treated whole flour.

On the other hand, PHI was significantly increased ranged from 5.40 to 5.94% for the same bread samples. These variations in transition temperatures and ΔHP between staled and fresh breads due to higher degree of crystallinity, structural stability of starch granules and interactions between the bread components (protein, lipid, Ca, starch), which make starch granules more resistant to gelatinization. Generally, as fermentation and baking time increased, a formation of ordered structure was achieved **(Coral et al., 2009; Wang and Les Copeland 2013).** The extent of retrogradation was found to be proportional to the melting enthalpy value, which this value express the energy needed to reorganized or melt the crystallized amylopectin during storage. The reassociation of amylopectin, amylose molecules or formation of amylopectin crystalline aggregates resulted from retrogradation. In addition, the migration of water was resulted from formation of amylopectin crystal hydrate consequence. After baking, in the first hours the amylose retrogradation was occured, while over storage time the amylopectin retrogradation takes place which increased the firmness of the whole pan bread (**Ding et al. 2019**). As shown in Table (10) the retrograde% of supplemented bread was significantly ($P<0.05$)

higher ranged from 90.00 to 94.00 when compared to control WF bread with value 88.60%. This is consistent with the decrease in enthalpy change (ΔHP) for staled bread (4.43-4.70) when compared with fresh bread at 0 time of storage (4.80-5.00 J.g^{-1}). The retrogradation of amylopectin can be considered a bread staling phenomenon causing a lowering in bread quality which observed by decreased in ΔHP during storage which resulted in higher staling rate (**Purhagen et al. 2012**).

Sensory evaluation and physical properties of chicken burger: Sensory properties of cooked burger under study are presented in Table (11) and Fig. (3). There are no significant (P<0.05) differences between the control chicken burger and the samples supplemented by 10%, 20% of DTWF in terms of tenderness, appearance and overall acceptability, as well as, these samples showed the best color among the others. The consumer acceptability which expressed by total score was highest for burgers containing 10%, 20% supplemented burgers, with values 59.30 and 56.60, respectively, as compared with 61.21 for control (100% chicken breast meat). Frying the burger in oil caused a decrease in the weight of the burger and decrease in cooking loss which ranging from 14.37-19.08% for supplemented burger, comparing with 21.54% for control. The shrinkage value of burger (as a result of changes in diameter, thickness after cooking) was decreased in supplemented burger ranged from 7.20-15.70% comparing with 15.96 for control. Consequently, the cooking yield was increased as a result of decreasing in shrinkage, cooking loss values was found in quantities from 79.29 to 86.25% for supplemented burgers samples, compared to 78.43% for control. This is in accordance with the findings of **Mikhail et al., (2014)**. From the above mention data there were a highly significant (p<0.05) differences between control burger and the 40% supplemented sample in all physical, sensory parameters which confirms that this ratio is gave undesirable results.

Table (11): Sensory evaluation and physical properties of chicken burgers supplemented with Dorado treated whole flour (DTWF).

Burger sample	**Sensory evaluation**								**Physical properties**		
	Color (10)	**Odor (10)**	**Tenderness (10)**	**Taste (10)**	**Texture (10)**	**Appearance (10)**	**Overall acceptability (10)**	**Total score (70)**	**Cooking loss (%)**	**Shrinkage (%)**	**Cooking yield (%)**
Control (100% CBM)	8.90	8.84	8.65	8.65	8.90	8.52	8.75	61.21	21.54	15.96	78.43
90% CBM + 10% DTWF	8.75	8.35	8.35	8.40	8.75	8.35	8.35	59.30	19.08	15.70	79.29
80% CBM + 20% DTWF	8.35	7.90	8.00	8.35	8.00	8.00	8.00	56.60	17.95	13.96	81.09
70% CBM + 30% DTWF	7.05	7.30	7.30	7.15	7.05	7.15	7.05	50.05	15.39	10.49	85.30
60% CBM + 40% DTWF	6.50	6.40	6.40	6.50	6.20	6.40	6.20	44.60	14.37	7.20	86.25
LSD 0.05	0.07	0.09	0.42	0.06	0.31	0.53	0.45	0.06	0.16	0.05	0.04

CBM: chicken breast meat.

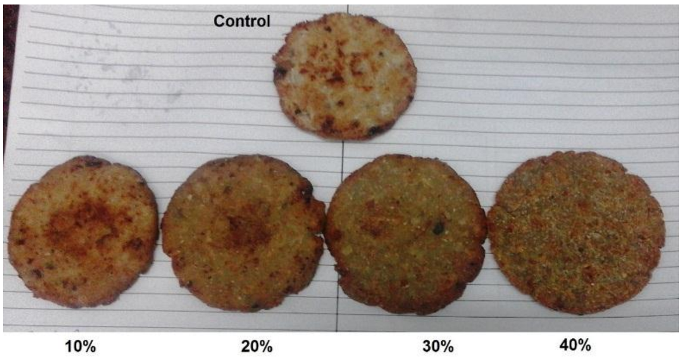

Fig. (3): The chicken burger made from chicken breast meat and its blends with Dorado treated whole flour (DTWF) at 10, 20, 30, 40% replacement ratios.

Chemical composition of chicken burger: The chemical composition (on a dry weight basis) of cooked chicken burgers without and with DTWF is recorded in Table (12). The moisture content of the DTWF cooked samples was significantly (P <0.05) lower (49.06-54.29) than the control (56.87%) sample as a result of binding the water by sorghum flour. The results also showed that all the studied samples contained significantly (P<0.05) high protein (40.70–58.44%), total carbohydrates (18.08-41.09%) and oil (10.46–13.64%) contents, consequently it have a higher energy content with range

421.30-428.84 Kcal/100g. It was observed that the increase in the amount of DTWF in the burger mixtures have been a significant decrease in chemical composition except total carbohydrates it was increased. Our data are in agreement with previous studies (**Mikhail et al., 2014; Valquı´ria *et al.*, (2016**).

Table (12): Chemical composition (% D.W.)* of cooked chicken burgers supplemented with Dorado treated whole flour (DTWF).

Burger samples	Moisture	Ash*	Oil*	Protein*	Crude fiber*	Total carbohydrates*	Energy* (Kcal/100 g)
Control (100% CBM)	56.87	5.10	13.64	58.44	4.74	18.08	428.84
90% CBM + 10% DTWF	54.29	4.83	12.95	55.51	4.60	22.11	427.03
80% CBM + 20% DTWF	53.01	4.56	12.08	51.48	4.57	27.31	423.88
70% CBM + 30% DTWF	50.26	4.02	11.50	45.64	4.19	34.65	424.66
60% CBM + 40% DTWF	49.06	3.89	10.46	40.70	3.86	41.09	421.30
LSD 0.05	0.05	0.06	0.12	0.08	0.09	0.06	0.05

CBM: chicken breast meat.

IV. CONCLUSION

The white sorghum grains are useful for human health and important. So, this research is concerned to deal with whole sorghum from its nutritional and technological importance. The soaking then heating of RWF has a decreasing different effect on minerals under study except Zn, Cu which did not change like K, Mg, Ca and Fe. The DTWF sample was lower in phytic acid content when comparing with the raw one. These differences in chemical composition of bread samples, whether increased or decreased, are due to the difference of these components in wheat flour and DTWF. The starch content was generally decreased, as ratio of DTWF increased in their bread samples. The gelatinization temperatures were significantly ($P<0.05$) different among the bread samples especially Te which found with higher degrees when compared to flours and flours mixtures. The change in enthalpy (ΔHP) of flours mixtures were significantly ($P<0.05$) different in comparison with bread samples. In addition, the ΔHP was significantly decreased for the stalled bread, which stored for 4 days. The quality parameters of chicken burger enriched with DTWF was varied in nutritional properties. The increase in the amount of DTWF similarly decreased lipid, protein and ash content, but total carbohydrates were increased in the burger samples. The results of the physical, sensory properties of the processed products with 10, 20% of DTWF gave a good results to the consumer, which confirms the importance of white sorghum whole flour from a nutritional point of view.

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