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Production and Evaluation of Gluten-Free Cakes

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Abstract: This study was carried out to use sorghum flour (SF), gelatinized corn flour (GCF), germinated rice flour (GRF), rice flour (RF), and their blends for production of gluten-free cakes suitable for celiac patients. Xanthan gum was used to improve the quality of cakes at level of 0.5%. Cake made of 100% wheat flour (WF) was prepared for comparison. Chemical composition, dough rheological properties, starch gelatinization**,** starch crystallinity**,** samples spectra by Fourier Transform Infra- Red (FT-IR), color attributes, staling rate, baking quality and sensory properties of cake were evaluated. A remarkable improvement in minerals (Ca, P, K and Fe), fat, and crude fiber was found in cakes prepared from SF and GCF as compared with control cake. Viscoamylograph and falling number parameters were significantly affected. Baking performance showed that all cake samples had lower volume and specific volume than control. Sensory evaluation of cakes indicated that all samples were acceptable, but sample which contained SF, GCF, and GRF (1:1:1) had superior sensory characteristics, nutritional value and was suitable for gluten – hyper- sensitive patients. FT-IR spectroscopy, DSC, x- ray techniques revealed remarkable differences in control and tested samples and supported the obtained results.

***Key words*:** Sorghum flour, gelatinized corn flour, germinated rice flour, wheat flours, rheological, sensorial, celiac patients, cakes

INTRODUCTION

Celiac disease or gluten sensitive enteropathy is a chronic disorder of the small intestine caused by exposure to gluten in the genetically predisposed individuals (Laurin *et al*., 2002; Hamer, 2005). It is characterized by a strong immune response to certain amino acid sequences found in the prolamin fractions of wheat, barley and rye (Hill *et al*., 2005). When people with celiac disease eat foods or use products containing gluten, their immune system responds by damaging or destroying the intestinal villi leading to the malabsorption of nutrients, thus adversely affecting all systems of the body (Feighery, 1999).

Celiac disease is now regarded as one of the most common genetic disorder, occurring in 1 of 130-300 of the global population (Fasano & Catassi, 2001; Fasano *et al* ., 2003). Intestinal symptoms can include diarrhea, abdominal cramping, pain and distention and untreated Celiac disease may lead to vitamin and mineral deficiencies, osteoporosis and other extra intestinal problems. The gluten-free diet remains until now the only treatment for Celiac disease. Gluten free diet has benefits such as the recovery of the villi of the small intestine and risk reduction of malignant complications (Seraphin & Mobarhan, 2002). Since the diet of Celiac patients must be completely free of any gluten, so all the products from wheat, rye, barley and oat must be replaced with corn, rice, millet equivalents and various types of starch (corn, rice and potato) or appropriate mixtures. Hydrocolloids (such as pectin, guar gum and xanthan gum) are added to naturally gluten-free flours to mimic the viscoelastic properties of gluten and to improve structure, sensory attributes and shelf-life of these products (Moore *et al*.,2006; Lazaridou *et al*., 2007). Also, soybean proteins were used for fortification of bakery products to improve their protein quality, mechanical behavior and shelf- life (Ribotta *et al*., 2004, Sanchez *et al*, 2004). When gluten-free flour is mixed to form dough, it does not form a continuous phase or dough structure and consequently fails to produce good quality bread (Ranhotra *et al*, 1975). Therefore, this study was designed to study the effect of using some different gluten-free flour mixtures (sorghum flour, gelatinized corn flour, germinated rice flour, rice flour and their blends) on the rheological properties of the dough. Also, evaluation of quality parameters of the baked cakes was another target.

MATERIALS AND METHODS

I-Materials:

Wheat flour (72% extraction) was purchased from the North Cairo Flour Mills Company, Egypt. Sorghum (Dorado) and White corn grains (Single cross 10) were purchased from the Corn Breeding Section, Field Crops Department, Agric. Res. Center, Giza, Egypt. Rice grains **(**Sakha 101**)** were obtained from Rice Research

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Department, Field Research Institute, Agric. Res. Center, Giza, Egypt. Shortening, skimmed milk, ground sugar, vanilla, eggs and baking powder were obtained from the local market, Cairo, Egypt. Xanthan gum was obtained from Sigma Chemical Co.(St.Louis, Mo), U.S.A.

Preparation of Flour and their Blends:

Sorghum and Rice grains were cleaned, tempered to 15% moisture content and milled using Quadrumat Junior flour mill for obtained whole flour. ***Gelatenized corn flour*** (GCF) was prepared according to Hussein *et al*. (2011). ***Germinated rice grains*** were prepared by steeping in distilled water at room temperature (28–30 ^{o}C) for 12 h. The steeping water was changed every 4 hrs. and drained at the end of soaking. The steeped rice kernels were distributed on a double layer of cotton cloth and placed in plastic basket. This basket was then covered by a double layer of cotton cloth. The germination took place in a germinating chamber for 24 hrs, at 28–30 ^{o} C, with 90–95% relative humidity, using an automatic sprinkler. The germinated seeds were dried at 50 ^{o} C till the moisture content in them reached 10%. The germinated grains were grounded to obtain fine powder 60 mesh and then stored in plastic containers for further use. Five flour blends were prepared and compared with control sample (100% WF) as follows: Sorghum flour (SF), gelatinized corn flour (GCF), germinated rice flour (GRF), rice flour (RF), mixture flour (MF) from SF, GCF and GRF (1:1:1), wheat flour (WF). Xanthan gum was added to all blends at 0.5% level except control. These samples were stored in air tight containers and kept in refrigerator (7ºC) till used.

FT-IR:

All spectra of the selected samples were measured using FT-IR system model FT-IR-6100 Jasco, Japan (Central Lab, National Research Centre, Egypt). All spectral data were recorded from 400 to 4000 nm.

Starch Crystallinity:

The crystallinity of starch was evaluated by X-ray diffraction patterns of samples using monochromatic Cuk radiation on a Philips X-ray diffract meter at 35 kv and 15mA (Central Lab, National Research Centre, Egypt). Lyophilized samples were placed on the l cm^2 surface of a glass slide and equilibrated overnight at 91% rh and run at 2-32°(diffraction angle 2θ). The spacing was computed according to Bragg's law (Gomez *et al*., 1992)**.**

Thermal Properties:

Starch gelatinization was studied in a differential scanning calorimeter (Mettler Toledo DSC 823-E, Switzerland) under oxygen free N2 flow rate of 50 ml/min, using 1:3 (w/v) starch-water mixtures. The samples were hermetically sealed in a pre-weighed aluminum pan at room temperature and re-weighed in a microbalance. After sealing the pan and leaving it to equilibrate for about 1 h, the samples were heated from 30 to 110°C at the rate of 10°C /min. An empty pan was used as a reference. The temperatures of the characteristic transitions, onset temperature (To), peak temperature (Tp) and end temperature (Te) were recorded and the temperature range (Te-To, ΔT) was calculated. The enthalpy (ΔHG) of the transition was expressed as mJ/g on a dry weight basis.

Rheological Properties:

Rheological properties of doughs were evaluated using Amylograph and Falling number test according to AACC (2000).

Preparation and Evaluation of Sponge Cakes:

Sponge cakes were prepared according to Bennion and Pamford (1997) with some modifications as follows: Flour (100gm), Xanthan gum (0.5gm) and baking powder (3gm) were mixed together; whole fresh eggs (125gm), sugar (100gm), skimmed milk (50gm), shortening (10gm) and vanilla (2gm) were whipped for 6 min. with using a mixer at high speed. Flour mixture was added gradually on the whipped milk-vanilla mixture and beaten for three min. using the mixer at low speed. One hundred and fifty grams of cake were poured in baking pans, then placed in a preheated oven and baked at 180ºC for 35 min. Cakes were allowed to cool for 30 min. in the pans at room temperature.

Analytical Methods:

Moisture, ash, fiber, protein and fat contents of raw materials and different cakes were determined according to AACC (2000). Total carbohydrates were calculated by difference. Individual elements (Ca, P, K, Na, Fe, Mn and Cu) in all samples were determined according to the method described by Chapman & Pratt [1978].Changes in Hunter color parameter (L, a &b) of raw materials and different cakes were followed up using Tristimulus Color Analyzer (Hunter, Lab Scan XE, Reston, Virginia) with standard white tile.

Baking Quality of Cakes:

Volume (cm^3) and weight (gm) of three cake samples of each treatment were recorded. Specific volume (gm/ cm^3) was calculated by dividing of the volume to weight according to the method described in AACC (2000).

Organoleptic Evaluation of Sakes:

Cake samples were evaluated for cells (30), grain (16), texture (34), crumb color (10) and flavor (10) according to the method described in AACC (2000).

Freshness of Cakes:

Cakes freshness was tested after wrapping with polyethylene bags and storing at room temperature (0, 1 and 3 days) using Alkaline Water Retention Capacity test (AWRC) according to the method of Yamazaki (1953), as modified by Kitterman & Rubenthaler (1971).

Statistical Analysis:

The obtained results were evaluated statistically using analysis of variance as reported by McClave & Benson (1991).

RESULTS AND DISCUSSION

1. Chemical Composition and Mineral Contents of Raw Materials and cakes:

Data presented in Table (1) showed and compared chemical composition and minerals content of flours and cakes of 6 types of SF, GCF, GRF, RF, MF and WF. Sorghum flour and cake produced from it were characterized with their higher contents of moisture, ash and crude fiber, and their lower content in total carbohydrate than GCF, GRF, RF, MF and WF. Gelatinized corn flour and cake produced from it were higher in fat content compared with SF, GRF, RF, MF and WF. Rice flour and cakes produced from it contained lower percentage of protein, fat, ash and fiber and higher content in total carbohydrate than GCF, GRF, RF, MF and WF. Wheat flour was the highest in the content of protein (13.56%) compared with other samples.

Results in Table 1 also indicated that flour and cake of SF was characterized with the highest value in calcium, phosphorus, potassium and iron (65.0, 410, 390 and 6.59 mg/100gm, respectively). The mineral contents of flour and cake of wheat were the lowest values, this due to the separation of germ and bran during milling, on contrary to GCF and WBF (Hussein *et al*., 2011). These results are due to the fact that, aleurone cells, together with the germ and testa contain the essential nutrients required for the growth and development of the embryo **(**Saxalpy &Venn-Brown, 1980 and Clysedale, 1994**)**. The obtained results were in agreement with those reported by Izydorczyk *et al*. (2001) and Hussein *et al*. (2006).

2. Identification of Functional Compounds of SF, GCF, GRF, RF, MF and WF Samples by Using FT-IR Technique:

Fourier Transform Infra- Red (FT-IR) spectroscopy was used to differential between SF, GCF, GRF, RF, MF and WF samples as a non- destructive, fast and simple technique. Since their flours contain different polar functional groups as lipids, carbohydrates and protein, FT-IR spectroscopy was used as a helpful tool to identify their chemical composition. Assignments of the FTIR absorption spectra bands of flour samples are tabulated in Tables 2 and (Fig. 1). The spectra of SF, GCF, GRF, RF, MF and WF samples observed between 4000-400 cm^{-1} in three regions : 3426-2857 cm^{-1}, 1742-1379 cm^{-1} and 12451-861 cm^{-1}. In the first region, broad band at 3408± 10cm^{-1} assigned to N-H and O-H vibration, 2925± 10cm^{-1} was attributed to C-H stretching asymmetric vibration and 2855± 10cm^{-1} for C-H stretching symmetric vibration. Amide1and amide 11that attributed to protein fraction were located at 1656 and 1540± 10 cm^{-1} , while fingerprint of flour samples were identified with board OH spectra bands of carboxylic acid, asymmetric stretching of CH, and stretching vibration of C=O of ester 3408± 10cm^{-1}, 2927± 10cm^{-1},and 1740± 10cm^{-1} . The third region corresponds to the spectral region of carbohydrate content in SF, GCF, GRF, RF, MF and WF, particularly carbohydrates show intense and characteristic bands in the region between (1251-861 cm^{-1})are assigned to N-H in-plane bend, C-N stretching, C-O-C stretching of starch, C-C stretching vibration, C-C stretching of starch, stretching C-O ring and pyranose ring and C-O-H, C-C-H, O-C-H deformation and these results in agreement with (Naumann, 2001)**.** The major peaks corresponding to carbohydrate content were located in the range 1157—1159 cm-1(stretching C-O-C) ,1019 cm-1(stretching C-O) and 860 cm-1 (stretching C-O-C-O) these results are in agreement with Kacura´kova´ *et al*., (2001). FT-IR spectra of different six samples showed that the GCF intensities of lipids and fingerprints have the highest values among other flour samples, while MF has high content of protein fingerprint. This was farther supported by proximate composition (table 1).

Table 1: Proximate composition and mineral contents of raw materials and cakes (On dry weight basis).

Constituents (%)	Raw materials of						Cakes produced from					
	SF	GCF	GRF	RF	MF	WF	SF	GCF	GRF	RF	MF	WF
Moisture	12.79±0.01	12.52±0.02	8.86±0.01	11.50±0.02	11.39±0.02	11.52±0.01	28.01±0.06	26.12±0.12	28.55±0.12	28.22±0.04	27.52±0.12	27.16±0.09
Protein	11.38±0.02	9.63±0.01	9.19±0.03	7.56±0.01	9.63±0.01	13.56±0.02	9.56±0.03	7.44±0.01	7.32±0.06	5.91±0.02	7.75±0.01	11.37±0.03
Fat	4.00±0.05	4.39 ±0.03	1.23 ±0.0	0.82±0.01	3.21±0.03	1.5±0.0	5.26±0.01	5.56±0.06	5.12±0.03	5.02±0.02	5.31±0.01	5.08±0.0
Ash	2.85±0.03	1.22±0.00	2.06 ±0.0	0.65±0.0	2.04±0.01	1.32±0.0	2.00±0.06	1.76±0.0	1.65±0.01	1.56±0.02	1.81±0.01	1.62±0.03
Crude Fiber	3.50±0.06	3.29 ±0.03	1.22 ±0.0	0.55±0.0	2.67±0.01	1.01±0.0	3.05±0.07	2.85±0.04	1.13±0.02	0.62±0.01	2.34±0.03	0.85±0.0
Carbohydrate*	78.27±0.88	81.47±0.72	86.30±0.52	90.42±0.65	82.45±0.56	82.61±0.71	80.13±0.22	82.39±0.45	84.78±0.36	86.89±0.32	82.79±0.66	81.08±0.72
Mineral (mg/100g):												
Ca	65.0±0.01	41.0±0.16	33±0.01	30±0.01	79.66±0.08	23±0.01	60.32± 0.35	35.07± 0.05	31±0.11	28±0.01	40±0.05	23.00± 0.13
P	410.0±0.03	230.0±0.11	360±0.03	333±0.16	333.33±0.09	190.1±0.09	400± 0.10	221± 0.81	320±0.13	325±0.16	313±0.62	190.0± 1.16
K	410.0±0.01	160.0±0.09	365±0.02	223±0.12	311.66±0.11	102.0±0.05	390± 0.25	132± 0.15	315±0.62	215±0.12	279±0.32	96.00± 0.75
Fe	6.59±0.02	3.50±0.03	2.50±0.0	1.47±0.01	4.19±0.03	1.71±0.0	6.32± 0.06	2.27± 0.08	2.22±0.0	1.27±0.01	3.6±0.01	1.82± 0.09

*Total carbohydrate was calculate by differences= 100- (% protein+ %fat+ %fiber+% ash)
SF = sorghum flour, RF= rice flour, GCF = gelatinized corn flour, GRF= germinated rice flour, MF= mixture flour, WF=wheat flour

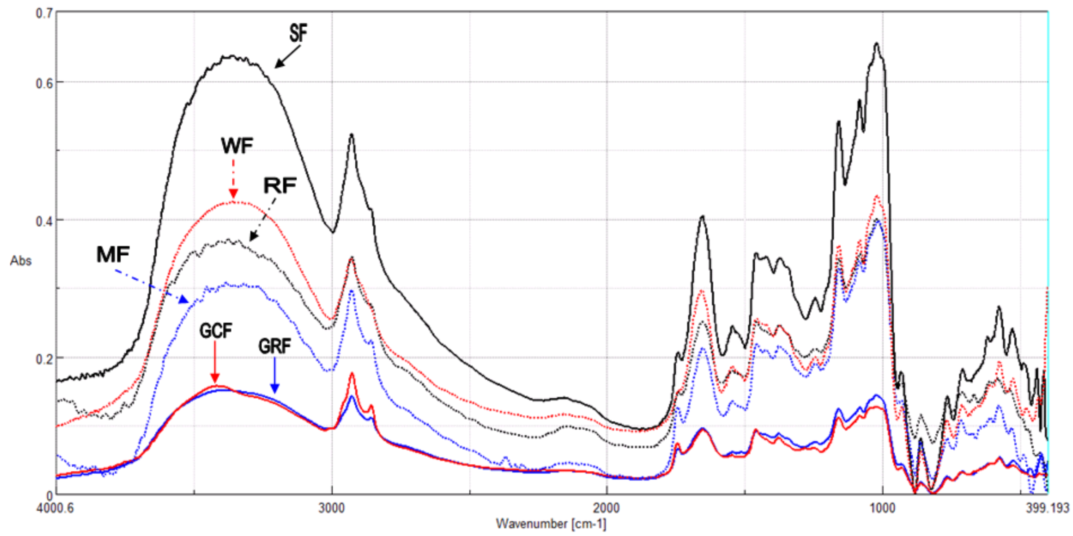


Fig. 1: FTIR spectra of SF, GCF, GRF, RF, MF and WF.
SF = sorghum flour, RF= rice flour, GCF = gelatinized corn flour, GRF= germinated rice flour, MF= mixture flour, WF=wheat flour

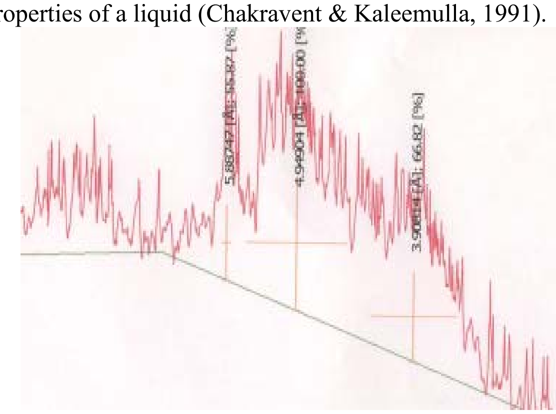
Table 2: FT-IR assignments and absorption regions of SF, GCF, GRF, RF, MF and WF.

ν Cm-1	SF (T%)	GCF (T%)	GRF (T%) 90 :10	RF (T%) 80 :20	MF (T%) 70:30	WF (T%) 60:40	Peak assignment
3356±10	23.14	70.73	69.73	42.72	49.44	37.75	Broad band, resulting from vibration of N-H with O-H group
2927±10	30.03	72.15	66.72	45.29	50.55	45.52	C-H stretching vibration asymmetric
1741±10	62.38	85.92	84.33	79.78	88.28	50.67	C-H stretching vibration symmetric
1652±10	39.49	80.27	80.66	56.23	90.67	65.18	C=O stretching vibration of ester
1545±10	56.99	81.05	80.64	66.26	90.13	55.7	Amide I (C=O stretch, N-H wag)
1459±10	44.71	81.76	80.62	56.32	74.86	56.96	Amide II (C-N stretching with N-H bending)
1370±10	45.51	75.21	82.77	56.81	61.52	63.35	C-H bending vibration
1243±10	51.97	74.87	79.16	45.62	73.39	43.64	δ(-C-H_2 -) of carbohydrates
1159±10	28.77	71.84	77.47	44.84	60.41	42.77	N-H in-plane bend, C-N stretch
1082±10	26.8	96.12	74.75	39.88	61.02	36.95	C-O-C stretching of starch
1021±10	22.19	94.31	88.72	69.01	64.69	74.83	C-C stretching vibration
932±10	66.51	92.71		76.7	46.97	86.59	C-C stretching of starch
861±10	82.93	88.43		73.91	45.93	77.99	Stretching C-O ring
763±10	72.09	89.37		42.72	40.16	74.22	(C6-C5-O5-C1-O1) ring and C-O-H, C-C-H, O-C-H deformation

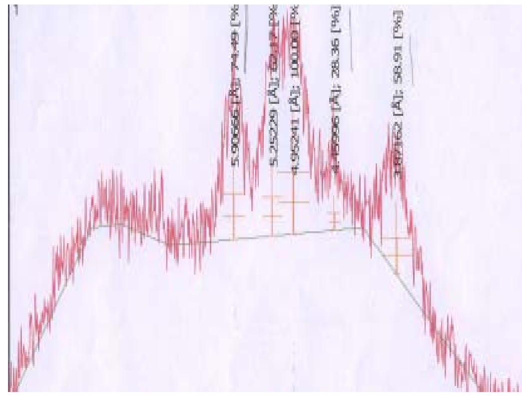
ν Cm-1: wave number(Cm-1), T%= intensity, SF = sorghum flour, RF= rice flour, GCF = gelatinized corn flour, GRF= germinated rice flour, MF= mixture flour, WF=wheat flour

3. Starch Crystallinity:

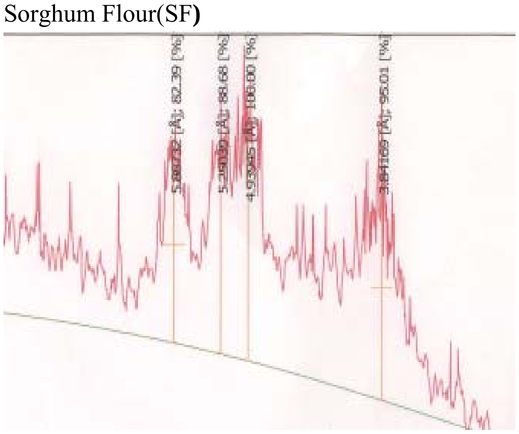
Changes of organized crystalline raw starch granules during cake preparation from SF,GCF, GRF, RF, MF and WF could be demonstrated by x-ray –technique. Starch granules are known to vary in their proportion of amylose and amylopectin, crystallite type (Zobel *et al*., 1988) and extent of amylopectin branching (De Boer, 1991). So X-ray diffraction patterns of such granules are subsequently varied. According to X-ray diffraction data, the structure of starch can be grouped into four types; A, B, C and V (Zobel *et al*., 1988). Fig. (2) Shows the diffractograms of analyzed samples and their respective crystallinity value. X–ray diffraction trace of the raw SF (Fig. 2) shows sharp diffraction peaks around 2θ value of 74.49, 28.36 and 58.91%, corresponding to d-spacing of about 5.9, 4.5 and 3.9 ºA, respectively. This pattern closely matches reported values of A-type cereal starches (Zobel *et al*., 1988). However, additional peak was observed at 2θ value of 17.5ºA (5.8 A d-spacing value). The diffractogram of GCF (Fig. 2) shows similar peaks with some shifting where these peaks appeared at 2θ value of 74.5, 62.3, 28.36 and 58.91%, indicating a d-spacing value of 5.9, 5.2, 4.4 and 3.8˚A, respectively. Also, another peaks were observed at 2 θ value of about 82.39, 88.68, 100 and 55 ˚% for GRF. Concerning RF (Fig. 2), the main peaks of A-type starches were observed with some shifts as well as additional peaks were recorded at d-spacing value of 5.9, 5.2 and 3.8 ºA. The diffractogram of (Fig. 2) revealed that structure of native starch granule is partially disrupted, where a less organized x-ray pattern is observed along with a development of diffractogram peak at about 3.8˚A (58.91% d-spacing value). This peak is the distinguishing feature of v-type starch (Arambula *el al*., 1998). MF and WF displayed another amorphous X-ray pattern (Serna-Saldivar *et al*., 1990) with a peak around 6.76̊A to 3.89˚A. Accordingly, the material is no longer a rigid but rather exhibits the properties of a liquid (Chakravent & Kaleemulla, 1991).



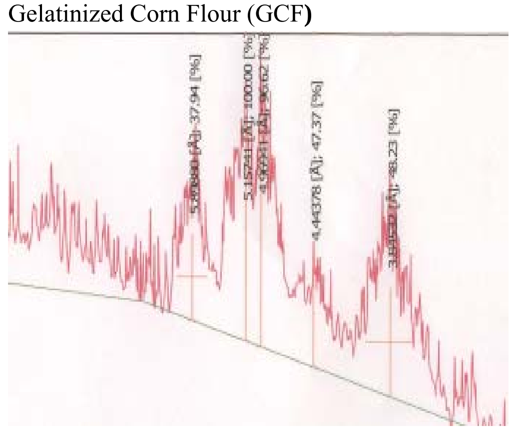
Sorghum Flour(SF**)**



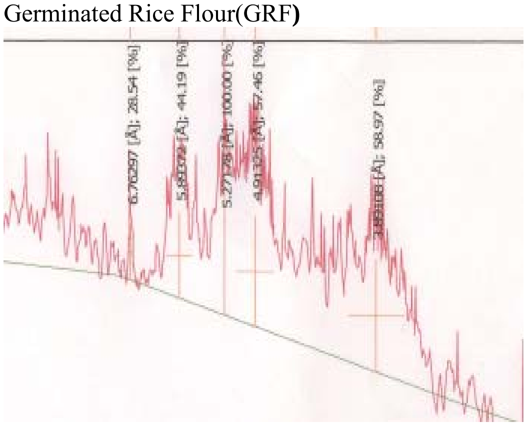
Gelatinized Corn Flour (GCF**)**



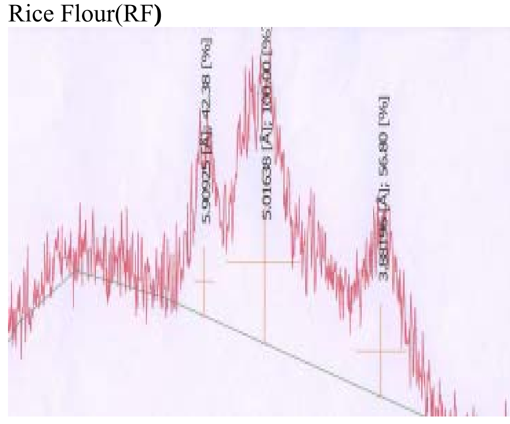
Germinated Rice Flour(GRF**)**



Rice Flour(RF**)**



Mixture Flour (MF**)**



Wheat Flour (WF**)**

Fig. 2: X – ray diffractograms of SF,GCF, GRF, RF, MF and WF.

4. Thermal Properties:

Table (3) shows gelatinization properties determined using DSC. DSC parameters recorded were onset To, Peak Tp, Final Te gelatinization temperatures, gelatinized temperature range (Te-To) gelatinization and enthalpy ΔH. Gelatinization temperatures and enthalpies associated with gelatinization endotherms varied between starches. To was 58.75, 68.72, 66.10, 69.73, 72.26 and 58.79 °C, Tp was 64.31, 72.45, 69.40, 62.13, 63.73 and 62.66 and Te was 75.42, 76.80, 74.10, 73.85, 75.62, and 67.02 for SF, GCF, GRF, RF, MF and WF, respectively. The gelatinized temperature range (Te-To) of starch was16.67, 8.08, 8.00, 4.12, 3.36 for SF, GCF, GRF, RF, MF and WF, respectively. Gelatinization temperature is considered a parameter of crystallite perfection because amylopectin plays a major role in starch granule crystallinity, the presence of amylose lower the melting temperature of crystalline regions and the energy for starting gelatinization (Tester *et al*., 1990). More energy is needed to intimate melting in the absence of amylose-rich amorphous regions. This correlation indicated that starch with higher amylose content has more amorphous region and lesscrystalline, lowering gelatinization temperature and endothermic enthalpy. Native and mixed starches with the same amylose contents as native starches showed clearly different gelatinization onset and peak temperature. The difference in gelatinization properties between native and mixed starches are due to varied homogeneity (Flipse *et al*.,1996). Fredriksson *et al.,* (1998) reported that a wide temperature range implies a large amount of crystals with varied stability. Also DSC parameters are also influenced by the molecular structure of the crystalline region which corresponds to the distribution of amylopectin short chain and not to the propagation of the crystalline region which corresponds to the amylase (Siau *et al*., 2004).

Table 3: Thermal properties of SF, GCF, GRF, RF, MF, and WF.

Samples	*T*o(°C)	*T*p(°C)	*T*e (°C)	ΔT(°C)	Δ*H* gel J/g
SF	58.75	64.31	75.42	16.67	24.9
GCF	68.72	72.45	76.80	8.08	9.52
GRF	66.10	69.40	74.10	8.00	9.22
RF	69.73	62.13	73.85	4.12	21.66
MF	72.26	63.73	75.62	3.36	18.34
WF	58.79	62.66	67.02	8.23	17.43

*T*o = onset temperature, *T*p = peak temperature, *T*e = end set temperature, ΔT= the temperature range (Te-To) and ΔH gel = Enthalpy of gelatinization, SF = sorghum flour, RF= rice flour, GCF = gelatinized corn flour, GRF= germinated rice flour, MF= mixture flour and WF=wheat flour

5. Viscoamylograph Measurements:

The amylograph measures the change in viscosity of a flour-water suspension as the temperature is raised at a uniform rate. The height of the amylogram peak is related to the gelatinization characteristics of the starch and the α-amylase activity (Shuey, 1975).

Dough was rheologically evaluated by viscoamylograph for temperature of transition, maximum viscosity, temperature of maximum viscosity, break down viscosity and set-back viscosity as presented in Table (4). Results showed that the highest value of temperature of transition was recorded for GCF, followed by GRF, MF, RF, WF and SF being 72.5, 72, 70, 69, 63 and 56.5 °C respectively. Farthermore, the maximum viscosity values were 610,1420, 1230, 1350, 1150, and 370 BU for SF, GCF, GRF, RF, MF and WF, respectively. The highest peak viscosity of GCF may be due to its lower amylase activity. The peak viscosity generally interpreted as an index of α- amylase activity present in the flour , the lower peak viscosity indicating higher level of alfa-amylase activity (Shuey and Tipples, 1982). These results are in agreement with those obtained by Kohlwey *et al* . (1995), they found that wheat flour had the lowest peak viscosity, and long – grain rice flour had the highest value. On the other hand, corn flour had intermediate value of peak viscosity.

From the same table, it could be observed that the pasting temperature value were 90, 95, 92, 89, 88 and 85°C for SF, GRF, RF, MF and WF, respectively. Dry corn masa had the highest value of Break down viscosity and set-back viscosity (1400 and 4660 BU), while, WF had the lowest value (160 and 410 BU).

Regarding the falling number, WF had the lowest falling number (284 s) than other samples, this result agreed with those found by Hussein *et al.* (2006). The results also indicated that both GRF (370s) and GCF (440s) demonstrated a low and very low activity of native α -amylase, which may suppress the amylolytic activity of the produced dough.

Table 4: Viscoamylograph parameters and Falling number of dough prepared from different flours.

Samples	Temp.of transition (°C)	Max. of Viscosity (BU)	Temp. of max. viscosity	Breakdown viscosity (BU)	Setback Viscosity (BU)	Falling No. (Sec)
SF	56.5	610	90	550	650	310
GCF	72.5	1420	95	1400	4660	440
GRF	72	1230	92	480	1300	370
RF	69	1350	89	530	1630	350
MF	70	1150	88	740	1420	367
WF	63	370	85	160	410	284

Bu: barabender units , SF = sorghum flour, RF= rice flour, GCF = gelatinized corn flour,
GRF= germinated rice flour , MF= mixture flour, WF=wheat flour

6- Color Attributes of Raw Materials and Cakes:

Color is one of the most important sensory attribute that affect directly the consumer preference of any product. Special attention should be given to bakery products to attract the consumer attention. The color parameters of raw materials and cake samples were evaluated using a Hunter laboratory colorimeter (table 5). The L scale ranges from 0 black to 100 white; the a scale extends from a negative value (green hue) to a positive value (red hue) and the b scale ranges from negative blue to positive yellow. GRF and cake from it was darker than SF, GCF, RF, MF and WF, where lightness (L^*) and redness values (b^*) decreased as type of flour used in cake processing. The same trend was observed in case of yellowness (a^*) of cake samples, where their values were getting higher in raw materials. This result could be attributed to the darkness of SF, GRF and GCF (lower L^*) than RF, MF and WF, so, darkness increased as a result of the presence of germ and bran in cakes. Such findings are in-agreement with Kim *et al*. (1997), Kordonowy &Young (1985) and Ramy *et al*. (2002).

Table 5: Hunter colour parameter of flours and cakes produced them.

Samples	Flours			Cakes					
				Crust			Crumb		
	L	a	b	L	a	b	L	a	b
SF	85	1.57	10.20	38.92	14.93	18.03	61.29	5.88	24.07
GCF	87.60	0.60	11.62	35.16	12.38	14.49	42.09	7.08	15.65
GRF	78.83	2.56	11.27	34.12	11.49	13.50	47.67	7.39	18.79
RF	84.23	1.42	10.40	39.12	13.27	16.67	48.26	6.34	18.36
MF	88.75	0.14	7.94	47.13	14.98	20.76	64.07	3.27	23.58
WF	92.33	0.45	9.53	50.74	14.06	23.05	53.03	6.69	20.71

SF = sorghum flour, RF= rice flour, GCF = gelatinized corn flour, GRF= germinated rice flour,
MF= mixture flour and WF=wheat flour

7-Baking Quality Of Cakes:

The physical characteristics of the produced cakes are presented in Table (6). Cake volume produced from WF (control) was highest compared with other samples, while cake weight produced from SF and MF were highest compared with other samples. This effect may be due to high fiber content in SF and MF. Fiber is characterized by their high water holding capacity. From the same table, specific volume of cake produced from WF had higher values compared with that of other samples. On the other hand, the processing of cake from MF specific volume was lower compared to those of the control. Yaseen *et al*. (2010)reported that loaf volume and specific volume were improved upon the addition of gums arabic and pectin. For instance, when 3% pectin or gum arabic were mixed with wheat – corn flour dough, the improvement of loaf volume and specific volume reached 27 and 29%, 25 and 24%, respectively.

8- Freshness of Cake:

The effect of storage period at room temperature on freshness of cake was evaluated. Table (6) showed that, the cake sample producing from RF had the highest values of alkaline water retention capacity which were declined during 0, 1 and 3 days of storage to 450, 410 and 385%, respectively. However, cake produced from GCF caused a noticeable decrease in alkaline water retention capacity values at the same storage period. Such effect might be related to the difference in quantitative distribution of protein fractions and physicochemical properties of starch of GCF. Such limited information is not sufficient to explain staling. Shittu *et al*. (2009) reported that moisture loss and crumb firming during bread storage were less reduced when 1% xanthan gum was added to bread formulations. According to Davidou et al (1996), the softening effect of bread was attributed to the increasing of gluten -starch interactions in the presence of hydrocolloids molecules.

Table 6: Freshness properties and baking quality of cakes.

Samples	Baking quality			Alkaline Water retention capacity (AWRC) (%) during storage		
	Weight (g)	Volume (cc)	Specific volume	Zero time	1 days	3 days
SF	140	255	1.82	410	375	350
GCF	120	288	2.4	390	320	280
GRF	130	284	2.18	400	380	350
RF	125	330	2.64	450	410	385
MF	140	240	1.71	410	380	350
WF	130	350	2.69	420	390	370

SF = sorghum flour, RF= rice flour, GCF = gelatinized corn flour, GRF= germinated rice flour,
MF= mixture flour and WF=wheat flour

9. Organoleptic Properties of Cake:

The organoleptic properties of cakes produced from SF, GCF, GRF, RF, MF and WF were evaluated for Cells, grain, Texture, Crumb color and flavor in Table (7) and illustrated in Fig.(3). The obtained results indicated that, sensory scores of cake for grain, Texture, and flavor of samples were not affected significantly in case of using SF, GCF, GRF, RF, and MF when compared with control cake sample (WF). A significant difference in Cells and crumb color was observed in all cake samples when compared with control cake sample (WF). Yaseen *et al* . (2010) reported that corn- wheat bread was significantly rated lower in sensory scores than the control bread, addition of 2% gum arabic or pectin had significant effects on the dough consistency and sensory acceptable of fresh composite bread.

Table 7: Organoleptic properties of cakes.

Samples	Cells (30)	grain(16)	Texture (34)	Crumb color (10)	Flavor (10)
SF	23.18^{bc}±2.82	13.36±1.12	26.45±4.47	7.91^{ab}±0.7	8.27±0.9
GCF	20.72^{c}±3.77	12.45±1.02	24.73±3.98	6.91^{b}±1.14	7.73±1.49
GRF	20.91^{c}±4.28	12.45±0.96	28.54±3.96	6.91^{b}±1.7	7.55±1.51
RF	25.27^{ab}±2.33	13.45±0.52	27.64±4.25	8.91^{a}±1.14	7.82±1.08
MF	23.36^{bc}±3.23	11.36±0.65	24.91±6.11	7.18^{b}±1.25	7.36±1.74
WF	27.27^{a}±1.63	13.45±1.12	29.0±3.85	8.27^{a}±1.03	7.45±1.51
LSD at 0.05	2.73	NS	NS	1.04	NS

SF = sorghum flour, RF= rice flour, GCF = gelatinized corn flour, GRF= germinated rice flour,
MF= mixture flour and WF=wheat flour

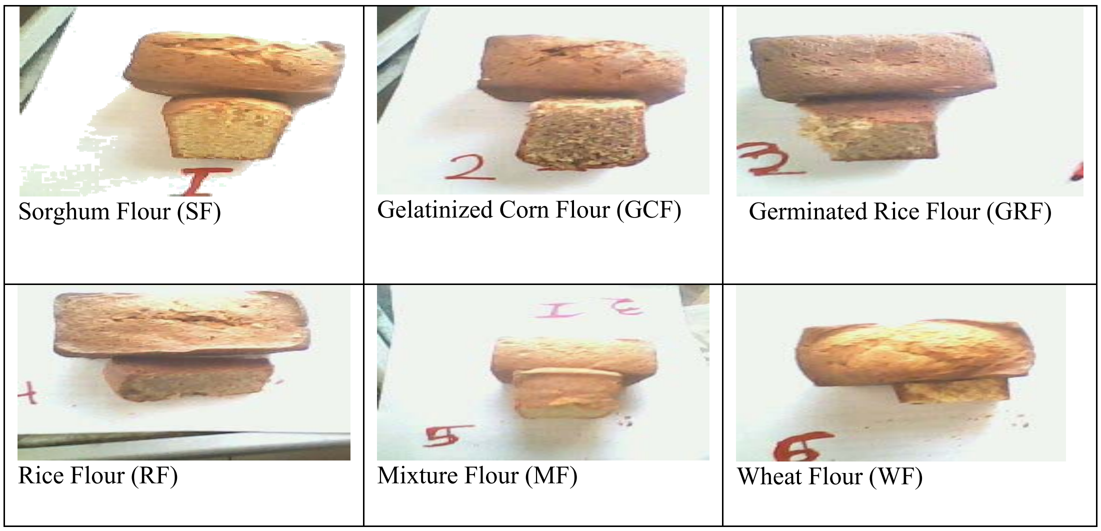


Fig. 3: Photo of cakes produced from SF, GCF, GRF, RF, MF and WF.

10. Conclusion:

Based on the previous study it could be concluded that all cake samples are suitable for gluten hyper-sensitive patients, but the sample which was made from MF contained 1% SF: 1% GCF: 1% GRF seems to be superior for sensory characteristics and nutritional value.

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