Middle East Journal of Applied Sciences
Volume: 12 | Issue: 01| Jan. – Mar. | 2022

EISSN: 2706 -7947 ISSN: 2077- 4613
DOI: 10.36632/mejas/2022.12.1.6
Journal homepage: www.curresweb.com
Pages: 47-58

Evaluation of quality and Thermal Analysis of Gluten Free Crackers making from cassava and sweet potato

Mahmoud A. El-Wakeel [1] and Samah M. Ismael[2]

[1]Food science Dept., Faculty of Agriculture, Bani-Suef Univ., Bani-Suef 62511, Egypt
[2]Home Economic Dept., Faculty of Specific Education, Ain Shams Univ., Cairo, Egypt

Received: 07 Dec. 2021 **Accepted:** 08 Jan. 2022 **Published:** 20 Feb. 2022

ABSTRACT

The proximate composition of sweet potato powder indicates that it possesses significant amounts of proteins, fat and fiber (8.16, 0.65, and 2.68%, respectively) while the cassava flour indicates significant amounts of proteins, fat and fiber (3.96, 0.48, and 4.78%, respectively). Cassava flour and sweet potato powder, also are rich in vitamins, as well as, various mineral constituents such as calcium, zinc and iron. All tested treatments showed that the sweet potato powder and cassava flour crackers were significantly contain higher nutrient contents compared to control crackers. In the current study, corn flour substituted with sweet potato powder and cassava flour till 100% of corn flour, gave crackers in formula 1 (100% sweet potato powder) with a better nutritional value in protein and fiber (87.5 and 1.17%, respectively). While formula 5 (100% cassava flour) show a high level of ash and carbohydrate (1.44 and 75.31%, respectively). The thermal analysis DSC (Differential scanning calorimetry) and TGA (Thermogravimetric analysis) presented a stable status for formula 5 (100% cassava flour) in enthalpy change (ΔH) 138.55 as well showed high sensory evaluation compared to the other formulas. Therefore, it could be concluded that, consuming cassava flour and sweet potato powder crackers could be used to provide a part of the daily requirements of protein, dietary fiber, carbohydrate, calcium, iron and zinc for of nutrients for with celiac disease and successes to prepared a good gluten free crackers product.

Keywords: Cassava, Sweet Potato, Gluten Free Crackers and Thermal Analysis

1. Introduction

Crackers are a type of bakery products. Crackers are species of snacks, light weight and expended between meals (Lusas, 2001). Diverse researchers have assessed the production of bakery products like crackers, biscuits and cookies with health reinforcement ingredients. (Julianti *et al.,* 2017). Tunick *et al.* (2013) reported that the cracker is usually described as crunchy.

Crackers were defined by Han *et al.,* (2010) as thin, crisp wafers, typically made of unsweetened and unleavened dough. Crackers are popular and worldwide consumed as low moisture baked goods (Kweon *et al.,* 2014).

Celiac disease (CD) is an immune system inflammatory illness of the small intestine system that's accelerated by the ingestion of gluten in hereditarily susceptible people (Singh *et al.,* 2018). Gluten is the type of protein primarily found in wheat other than a few other cereal grains such as rye and barley (Rosell *et al.,* 2014).

Dietary treatment for celiac disease is based only on a stringent gluten-free diet in which dietary wheat, barley and rye are excluded. This was described to improve histological lesions, clinical manifestations and the risk of celiac disease related complications (Ciacci *et al.,* 2002).

Cassava flour is a major food staple in Africa, South America and Caribbean, cassava flour as a substitute for wheat flour in bakery products as an economically and cheap (Abass *et al.,* 2018). A major advantage in using for applying cassava resource is to greatly increase the choice and variety of staple foods for a large people, especially as a type of important gluten-free food for persons with celiac

Corresponding Author: Mahmoud A. El-Wakeel, Food Science Dept., Faculty of Agriculture, Bani-Suef Univ., Bani-Suef 62511, Egypt.

disease (Bascuñán *et al.,* 2017). Usal *et al.* (2007) indicated that cassava flour can be used on a several food industries and the major utilization is in the starch production, chips production, sweeteners like high fructose and glucose syrup.

The trend in utilization of sweet potato (*Ipomoea batatas (L.) Lam*) is shifting away from its use as a staple food to use it as a processed food, a raw material for industrial products (Chen *et al.,* 2003). The carbohydrate composition in sweet potato roots greatly affects the eating quality and processing traits (Oladeyebe *et al.,* 2009). Sweet potatoes are an economical and a healthy food crop containing high β-carotene, substantial of ascorbic acid and minerals amounts (Lee *et al.,* 2002). Sweet potato flours were applying to use for specific requirements like in soups, sauces, snacks, etc., therefore, knowledge on functional and physicochemical characteristics of its starch is essential. (Tetchi *et al.,* 2007). Pramodrao and Riar, (2014) reported the use of dried and ground sweet potato as a supplement in noodles and other wheat-based baked foods.

The current study aimed to prepare and determine the nutritional value, physical properties and thermal properties of gluten free crackers substituted with cassava flour and sweet potato powder as a natural supply of nutrients for celiac disease populations.

2. Materials and Methods

2.1. Materials

Cassava tubers (*Manihot esculenta*), Nigerian variety, were obtained from the farm of Horticultural Research Institute, Agricultural Research centre, Giza, Egypt., Yellow corn flour, and other baking materials: salt, sugar, butter, and baker's yeast were purchased from a local market a Cairo. Sweet potatoes *(Ipomoea batatas L. Lam)* were obtained from a local market, Cairo, Egypt.

2.2. Methods

I. Preparation of Cassava and sweet potato as powders.

Cassava tuber was processed according to the method described by Mosha *et al.* (2000). After tubers washing, it was peeled and cut into slices and soaked in water at a ratio of 1: 2.5, (cassava slices: water) at room temperature for 24h .The cassava slices were washed in a large amount of distilled water, squeezed and dried at 60°C for 12h, in air oven. The dehydrated product was milled to a fine powder, then packed into polyethelen bags and stored in a deep freezer until using. While the sweet potato after cleaning, peeling and trimming they were sliced by special tools in cubic form and blanched in hot water at 95°C for 5 min. After which they were washed in cold water, dry in a air oven at 65 ºC for overnight and milling in a powder form.

II. Preparation of Crackers

For making crackers, the procedure by Han *et al.* (2010) was followed, with some modifications. Table (1) shows the crackers ingredients.

Table 1: Gluten free crackers formulations Ingredients

Ingredients (g)	Samples					
	Control	F1	F2	F3	F4	F5
Yellow Corn Flour	100	-	-	-	-	-
Cassava	-	0	25	50	75	100
Sweet potato	-	100	75	50	25	-
Shortening	10	10	10	10	10	10
Salt	1.5	1.5	1.5	1.5	1.5	1.5
Starch	4	4	4	4	4	4
Sodium Bicarbonate	0.2	0.2	0.2	0.2	0.2	0.2

The ingredients of each formula are shown in Table (1). For the preparation of gluten-free crackers the shortening, salt and water were mixed in a mixer Moulinex mixer model Supermix150 for 1 minute, then scraped down, and continued to mix for 3 minutes. Dry ingredients (yellow corn flour, cassava and sweet potatoes) and baking powder were progressively added to mixture and mixed at a low speed for 3 minutes after this the dough of crackers were left to rest for 15 min., then sheeted and the dough were formed using the templates with an outer diameter of around 5 mm and thickness of 3 mm. The crackers were baked at 170º C for 15 min, after baking the crackers were let to cool around 1 h at room temperature and packaged in polyethelen bags until used.

III. Chemical Composition

Moisture, protein, fat, crud fiber, ash and minerals (Na, Ca, P, Mg, Zn and Fe) content; of the investigated samples and crackers were carried out according to the AOAC (2012). Total carbohydrates are given by difference. On the other hand, total calories were calculating as mentioned by James, (1995) according to the equation of Total calories= 4 (%Protein + % Carbohydrates) + 9 (% fat).

Vitamin B complex was determined using HPLC (Agilant Technologies, Germany, 1200 series equipped with a variable wave length detector) according to the method described by Batifoulier *et al.* (2005). Vitamin A was determined using HPLC according to the method described by Plozza *et al.* (2012).

IV. Physical Characteristics of Crackers

Crackers were evaluated for weight (g) thickness (mm) and volume (cm^3) as described by Gaines (1991). Six crackers edge-to-edge were used for the evaluation and the average was noted. Diameter and thickness were measured using a Vernier Caliper, while the specific volume =volume /weight (cm^3/g). However, the crackers hardness was determined using a feature Texture Profile Analyzer (TPA) according to AACC (2002). Hardness was calculated from TPA graphic in Newton (N).

2.3. Thermal Analysis

I. Differential Scanning Calorimetry (DSC)

DSC measurements were carried out by DSC-60 (Shimadzu Co.; Kyoto, Japan) calorimeter at temperatures within 50-200 ºC in an inert gas stream (nitrogen). The measurements of the tested samples were performed using around 10 mg of each sample which were put into an aluminum pan. A sample pans were heated at a rate of 10ºC/min from 50–200ºC. Onset temperature (To); peak temperature (Tp); conclusion temperature (Tc) and enthalpy of gelatinization (ΔH gel) were automatically calculated (Kaur *et al*., 2002). The gelatinization temperature range (Rt) was computed as (Tc-To) as described by Vasanthan and Bhatty, (1996). Enthalpies were calculated on a sample dry basis. The peak height index (PHI) was calculated by the ratio of ΔH/ (Tp-To) as described by Mousia *et al*. (2004).

II. Thermogravimetric analysis (TGA)

TGA was carried out by a Shimadzu TGA-50H (Japan) apparatus, the measurements of the tested sample were performed using about 10 - 20 mg of each sample. Samples were heated from 20 to 600ºC with a heating rate of 10ºC/min. Analyses were carried out under a nitrogen atmosphere with a 20 ml/min flow rate using alumina cell. Degradation temperatures were determined from the DTG scans, as the peak maximum (Averousa and Boquillon, 2004). Thermogravimetric Analyzer Nitrogen gas-Japan.

III. Sensory Evaluation

Crackers samples were organoleptic evaluated for its sensory characteristics. A crackers sample was served on white, odorless and disposable plates and water was provided for rinsing between samples for ten panelists. Samples were scored for appearance, color, flavor, texture, taste and crispiness. Control corn crackers were used to compare with our product for sensory test. The evaluation was carried out according to the method of Wanyo *et al.* (2009).

2.4. Statistical Analysis

The analytical data were statistical analyzed using SPSS 20.0. Means and standard deviations were determined using descriptive statistics. Comparisons between samples were determined using analysis of one-way variance (ANOVA) and multiple range tests. Statistical significance was defined at $P \leq 0.05$.

Middle East J. Appl. Sci., 12(1): 47-58, 2022
EISSN: 2706 -7947 ISSN: 2077- 4613 *DOI: 10.36632/mejas/2022.12.1.6*

3. Results and Discussion

The proximate compositions of yellow corn flour, sweet potato and cassava powder are presented in Table 2.

Results in Table (2) showed the moisture content of cassava flour was 9.16%, while the moisture content of sweet potato was 5.45%. It is clear that, these results are in accordance with the results reported by Dudu *et al.* (2019). However, from results mentioned in Table (2) it is clear that the crude protein content of sweet potato almost doubles the amount of protein content of cassava flour a roughly equal of protein content yellow corn flour accepted with Padonou *et al.* (2005).

Results also showed that the ash content of sweet potato powder was 2.9%, while cassava flour was 3.55% and yellow corn flour was 1.16%. These results are accordance with Ogbo and Okafor (2015), where these data indicated that partial substitution of sweet potato powder by cassava flour increase the ash content, with increasing of substitution level. The obtained results presented the cassava flour had a high content of crude fiber 4.78% followed by sweet potato 2.68%, compared to its content of yellow corn flour which was 1.20%. while the lipid content of sweet potato powder was 0.65%, while the lipid content of cassava flour was 0.48 %. These results of crude fiber and lipids are in agreement with those reported by Ihediohanm, (2010). The obtained results in table (2) declared that the total carbohydrate contents of cassava and sweet potato powders were higher 87.67 and 85.93% compared with yellow corn flour (75.01). These results agreed with Erbas *et al.* (2005).

Table 2: Chemical composition, minerals and vitamins contents of raw materials.

Parameters	Chemical composition g/ 100g (dry weight)		
	Yellow Corn Flour	**Cassava flour**	**Sweet potato powder**
Moisture	12.95 ^{a} ±0.03	8.16 ^{b} ±0.05	5.45 ^{c} ±0.05
Crud Protein	8.55 ^{a} ±0.21	3.96 ^{c} ±0.22	8.16 ^{ab} ±0.24
Crud Fat	2.14 ^{a} ±0.04	0.48 ^{b} ±0.05	0.65 ^{c} ±0.07
Ash	1.16 ^{c} ±0.20	3.55 ^{a} ±0.25	2,95 ^{b} ±0.22
Crud Fiber	1.20 ^{b} ±0.07	4.78 ^{a} ±0.14	2,68 ^{c} ±0.11
Carbohydrate by different	75.01 ^{c} ±0.53	83.85 ^{b} ±0.11	85.74 ^{a} ±0.46
	Mineral (mg/ 100g dry weight)		
Na	42.00 ^{c} ±0.53	124.92 ^{a} ±0.46	228.00 ^{b} ±1.12
Ca	20.85 ^{c} ±0.09	52.29 ^{a} ±0.15	24.85 ^{b} ±0.15
P	272.00 ^{b} ±0.07	68.00 ^{c} ±0.11	295.00 ^{a} ±0.12
Mg	93.00 ^{b} ±0.12	145.29 ^{a} ±0.12	85.00 ^{c} ±0.07
Zn	2.72 ^{b} ±0.25	0.73 ^{c} ±0.30	3.02 ^{a} ±0.21
Fe	4.60 ^{b} ±0.06	1.46 ^{c} ±0.10	5.73 ^{a} ±0.09
	Vitamins (dry weight)		
Vit A (IU)	42.30 ^{b} ±0.08	34.00 ^{c} ±0.07	4150.00 ^{a} ±0.12
Thiamine B1 (mg/100gm)	0.21 ^{c} ±0.02	0.25 ^{b} ±0.01	0.36 ^{a} ±0.02
Riboflavin B2 (mg/100gm)	0.07 ^{c} ±0.01	0.12 ^{b} ±0.01	0.26 ^{a} ±0.01
Niacin B3 (mg/100gm)	1.75 ^{c} ±0.04	2.13 ^{b} ±0.07	2.43 ^{a} ±0.09
Vit B6 (mg/100gm)	0.35 ^{b} ±0.03	0.22 ^{c} ±0.03	0.90 ^{a} ±0.01

Values are means of three replicates ±SD.
Values number in the same raw followed by the same letter are not significantly different at $p<0.05$ level

The cassava flour and sweet potato powder are rich in various mineral constituents. The predominant mineral was magnesium followed by sodium, phosphorous, calcium, magnesium, zinc and iron (Bedier, 2004). Results on cassava flour agreed with that found by Alonso-Gomez *et al.* (2016).

The results showed an increase in the sodium content of sweet potato powder, reaching 228 mg/100g, which is almost double the value in cassava flour, which is almost five times that of yellow corn flour , while the calcium content of cassava flour was 52.29 mg/100g, which is almost double the amount found in sweet potato powder is almost equal to that in yellow corn flour however, the content of phosphorous in sweet potato powder reached 295 mg/100 g , which is five times that of sweet potato powder . Whereas, sweet potato powder's iron and zinc contents were 5.73 mg/100 g and 3. 20 mg / 100 g, respectively, which is about four times the amount in cassava flour and were very closed to the value of yellow corn flour, while magnesium reached 145.29 mg / 100 g which is twice the amount in yellow corn flower and sweet potato powders agreed with Montagnac *et al.* (2009).

The results showed a high content of sweet potato powder of vitamin A, which amounted to 4150 IU, compared to cassava flour and yellow corn flour (34 IU and 42.30 IU, respectively). however, the result presented a high content of vitamin B group (B1, B2, B3 and B6) in the sweet potato powder Thiamine B1, Riboflavin B2, Niacin B3 and Vit B6 content were(0.36, 0.26, 2.43and 0,90 mg/100 g, respectively),compared to cassava flour and yellow corn flour, thus the sweet potato powder is richer than the content of vitamin B group as reported by El-Bedawy *et al.* (2009).

3.1. Chemical Composition and Nutritional Value of Crackers

The chemical compositions of the crackers are given in Table 3. All the tested parameters tested showed that the sweet potatoes and cassava flour crackers had significantly higher nutrient content compared to control crackers ($p<0.05$).

The results in Table (3) show that moisture content in crackers (F1) with 100% sweet potato powder was significantly higher (4.53%) than control (4.13%). The results presented that the F1 (100% sweet potato powder) was the highest content of protein (8.75 %) and a gradual decrease in the protein percentage was observed with the ratio of cassava flour increased, reaching 7.76 % in the treatment F5 (100% cassava flour). The ash content in the F1 (100% cassava flour) shows the highest value (1.191%) and the amount of ash increased with an increase in the percentage of cassava flour,as well as the increase in fiber content in the F5 (100% in cassava flour) and F4(75% in cassava flour + 25% sweet potato powder) and decreased with increasing the content of sweet potato powder to reach to 1.17% in F1(100% sweet potato powder). The carbohydrates in all treatments ranged from 76.24 in F5(100% cassava flour) to 73.94 in F2(75% sweet potato powder + 25% cassava flour). As expected, the total energy increased with the increase cassava flour as a result of increase in carbohydrate contents with a stable fat content in all treatment of crackers agreed with Agrahar-Murugkar *et al*. (2018).

Table 3: Chemical Composition and Caloric Values of the Prepared Crackers.

	Moisture	Protein	Fat	Ash	Fiber	Carbo-hydrate	Total Energy (Kcal /100g)
Control	$4.13^{c} \pm 0.01$	$8.23^{c} \pm 0.03$	$11.79^{a} \pm 0.02$	$1.42^{e} \pm 0.03$	$1.02^{d} \pm 0.02$	$74.53^{d} \pm 0.03$	$436.75^{e} \pm 0.12$
F1	$4.53^{a} \pm 0.04$	$8.75^{a} \pm 0.03$	$11.76^{a} \pm 0.07$	$1.41^{e} \pm 0.05$	$1.17^{c} \pm 0.07$	$74.96^{c} \pm 0.06$	$440.68^{c} \pm 0.23$
F2	$4.34^{b} \pm 0.07$	$8.49^{b} \pm 0.06$	$11.74^{a} \pm 0.05$	$1.49^{d} \pm 0.02$	$1.30^{b} \pm 0.05$	$73.94^{f} \pm 0.08$	$435.38^{d} \pm 0.33$
F3	$4.12^{c} \pm 0.05$	$8.36^{c} \pm 0.07$	$11.7^{a} \pm 0.06$	$1.66^{c} \pm 0.06$	$1.33^{b} \pm 0.09$	$74.11^{e} \pm 0.05$	$435.63^{d} \pm 0.14$
F4	$4.13^{c} \pm 0.02$	$8.24^{c} \pm 0.07$	$11.73^{a} \pm 0.05$	$1.78^{b} \pm 0.04$	$1.43^{a} \pm 0.07$	$75.9^{b} \pm 0.02$	$442.13^{a} \pm 0.11$
F5	$4.26^{b} \pm 0.04$	$7.76^{d} \pm 0.03$	$11.74^{a} \pm 0.05$	$1.91^{a} \pm 0.02$	$1.44^{a} \pm 0.06$	$76.24^{a} \pm 0.01$	$441.66^{b} \pm 0.31$

Values are means of three replicates ±SD. Values number in the same raw followed by the same letter are not significantly different at $p<0.05$ level

3.2. Mineral and Vitamin Composition

The sodium in treatment F1(100% sweet potato powder) was 205.13 mg/100gm) represented half of the amount in treatment F5 (100% cassava flour) which was 101.12 mg/100gm, while the calcium recorded the highest percentage in treatment F5 and it decreases by increasing the concentration in the cassava flour to reach the lowest value in F1 (100% sweet potato powder) and control yellow corn flour .The treatment F5 (100% cassava flour) recorded the highest value of magnesium, phosphorous and zinc and the value were 102.41, 242.41and 2.64 mg/100gm,respectively, and the percentage decreases as the concentration of cassava flour decreased and the concentration of sweet potato powder increased. However a high percentage of iron was 4.83 mg/100gm was observed in the F1(100% sweet potato powder), whereas F5 (100% cassava flour) recorded the lowest value of iron and less than the control sample, concurrently with El-Bedawy *et al.* (2009).

Vitamin A contents decrease with increasing the substation level of, since the source of vitamin A is sweet potato powder. While vitamin B complex showed an increase with increasing of sweet potato powder level agree with Ugwuona *et al.* (2017).

Table 4: Mineral and Vitamin Composition of the Prepared Crackers.

	Control	F1	F2	F3	F4	F5
			Minerals			
Na (mg/100gm)	94.12 ^{f}± 0.02	205.13 ^{a} ±0.01	170.25^{b}± 0.76	122.1 ^{c} ± 0.23	107.67 ^{d} ±0.21	101.11^{e} ± 0.12
Ca (mg/100gm)	146.34 ^{e} ± 0.02	146.35 ^{e} ±0.04	149.64^{b}± 0.03	147.75 ^{c} ± 0.05	161.74 ^{b} ± 0.04	189.85^{a} ± 0.04
P (mg/100gm)	261.05^{a} ± 0.07	81.28 ^{f} ± 0.12	94.53 ^{e} ± 0.25	107.29 ^{d} ± 0.23	187.13 ^{c} ± 0.25	242.41^{b} ± 0.22
Mg mg/100gm)	60.21 ^{c} ± 0.09	32.32 ^{e} ± 0.04	54. 27 ^{d}± 0.05	56.24 ^{d} ± 0.03	83.44 ^{b} ± 0.13	102.41^{a} ± 0.12
Zn (mg/100gm)	2.18 ^{d} ± 0.09	1.61 ^{f} ± 0.03	1.95 ^{e} ± 0.1	2.14 ^{c} ± 0.02	2.31 ^{b} ± 0.11	2.64 ^{a} ± 0.14
Fe (mg/100gm)	1.52 ^{e} ± 0.06	4.83 ^{a} ± 0.03	3.35 ^{b} ± 0.06	2.36 ^{c} ± 0.01	1.97 ^{d} ± 0.03	1.17 ^{f} ± 0.02
			Vitamins			
Vit A (IU)	32.21 ^{e} ± 0.05	3571.32 ^{a} ± 0.05	2607.87^{b}± 0.06	2001.87^{c}± 0.05	265.53 ^{d} ± 0.03	27.7 ^{f} ± 0.04
Thiamine B1 (mg/100gm)	0.16 ^{c} ± 0.04	0.16 ^{c} ± 0.01	0.17 ^{c} ± 0.02	0.21 ^{b} ± 0.04	0.21 ^{b} ± 0.02	0.25 ^{a} ± 0.03
Riboflavin B2(mg/100gm)	0.05 ^{c} ± 0.04	0.04 ^{c} ± 0.01	0.04 ^{c} ± 0.01	0.05 ^{b} ± 0.03	0.07 ^{b} ± 0.05	0.09 ^{a} ± 0.02
Niacin B3 (mg/100gm)	1.28 ^{a} ± 0.07	1.27 ^{a} ± 0.04	1.29 ^{a} ± 0.03	1.11 ^{b} ± 0.09	1.13 ^{b} ± 0.03	1.11 ^{b} ± 0.06
Vit B6 (mg/100gm)	0.20 ^{e} ± 0.04	0.46 ^{a} ± 0.09	0.41 ^{b} ± 0.03	0.37 ^{c} ± 0.07	0.29 ^{d} ± 0.03	0.27 ^{d} ± 0.04

Values are means of three replicates ±SD.
Values number in the same raw followed by the same letter are not significantly different at $p<0.05$ level.

3.3. Physical Properties

Physical characteristics of crackers are very important for consumers and manufacturers. Too much elasticity (gluten) in the dough will spring back to give thicker crackers with smaller diameter; while too little elasticity may cause the dough to flow after molding, resulting in thin crackers with larger diameter (**Mian *et al.*, 2009**).

Table 5: Physical characteristics of prepared crackers.

	Control	F1	F2	F3	F4	F5
Weight (gm)	2.86 ^{a} ±0.06	2.96 ^{a} ±0.02	2.92 ^{a} ±0.07	2.85 ^{a} ±0.06	2.84 ^{b} ±0.03	2.84 ^{b} ±0.09
Thickness (cm)	0.21 ^{a} ±0.06	0.21 ^{a} ±0.07	0.21 ^{a} ±0.02	0.21 ^{a} ±0.05	0.21 ^{a} ±0.08	0.21 ^{a} ±0.03
Volume (cm^3)	0.85 ^{b} ±0.02	0.89 ^{a} ±0.03	0.83 ^{b} ±0.03	0.84 ^{b} ±0.02	0.83 ^{b} ±0.02	0.82 ^{b} ±0.02
Specific Volume (cm^3/g)	0.30 ^{b} ±0.01	0.30 ^{b} ±0.01	0.29 ^{a} ±0.01	0.29 ^{a} ±0.01	0.29 ^{a} ±0.01	0.29 ^{a} ±0.01
Hardness (N)	25.61 ^{a} ±0.04	23.98 ^{c} ±0.05	24.83 ^{b} ±0.02	24.98 ^{b} ±0.02	25.63 ^{a} ±0.01	25.96 ^{a} ±0.02

*Values are means of three replicates ±SD.
Values number in the same raw followed by the same letter are not significantly different at $p<0.05$ level.

The results of the cracker weight are shown in Table 5. weights of cracker were reduced and thickness were increased with increasing level of with sweet potato powder with stability thickness in all samples

These results were similar to those reported by Agrahar-Murugkar *et al*. (2018). As for the weight and thickness, Demirkesen (2016) suggested that spread ratio is affected by the competition of ingredients for the available water; flour or any other ingredient which absorbs water during dough mixing will reduce it.

EISSN: 2706 -7947 ISSN: 2077- 4613 *DOI: 10.36632/mejas/2022.12.1.6*

The results of the cracker specific volume are shown in Table 5. Inclusion of F2 (50% cassava + 50% sweet potato powder) resulted in crackers with lower specific volume than that of the control cracker

Cracker hardness is defined as the (maximum force required to break or fracture the product. The addition of different levels of sweet potato and cassava flours resulted in crackers with a reduced hardness compared with the control cracker. Such results could be regarded to that the crackers containing sweet potato powder had a higher total fiber content flowed by cassava flour compared with the control cracker (Table 3). O'Shea *et al.* (2017) found that, as the level of sweet potato powder increased, the biscuit hardness or breaking strength decreased.

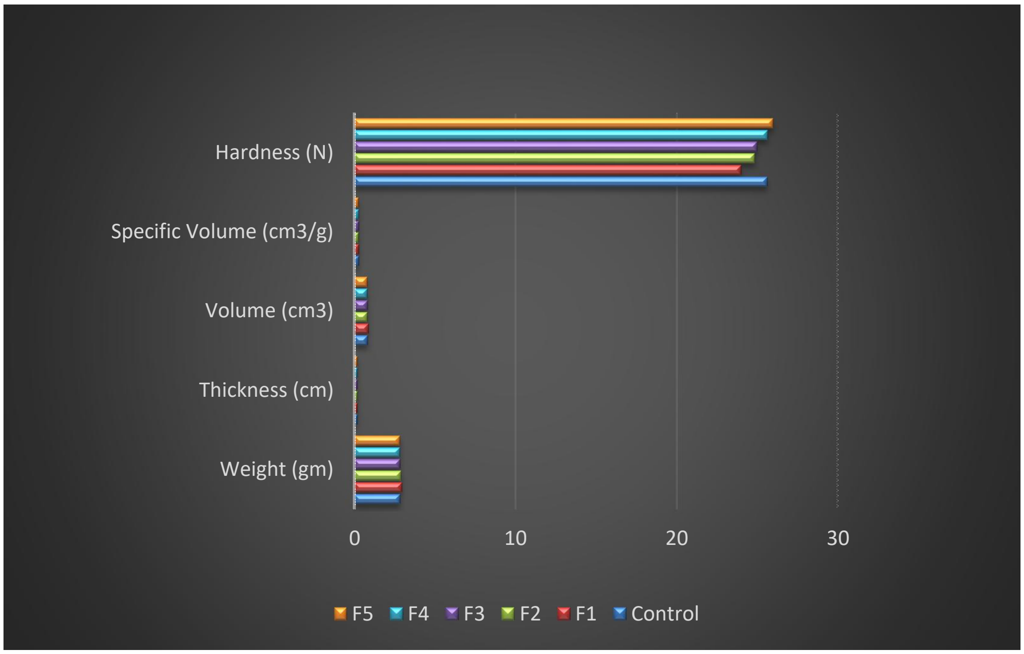

Fig. 1: Physical properties of prepared crackers

3.4. Thermal analysis

Differential scanning calorimetry (DSC) has been used to study changes in proteins and starches as a function of temperature (Haynes and Schuenzel, 2011). These changes are reflected in the DSC curve. Under controlled conditions of heating rate, thermal stability of samples can be monitored by the onset temperature (To) or peak transition temperature (Tp), while the transformed proportion is reflected by the area under the endothermic peak, representing the enthalpy change (ΔH)

Onset temperature (T_0) of all the tested samples ranged from 32.86 ºC in F5 (100% cassava flour) to 319.42 ºC in F2 (25% cassava flour + 75 sweet potato powder). The peak gelatinization temperature (Tp) was the highest one (331.44 ºC) in F4 (75% cassava flour + 25% sweet potato powder) sample followed by F3 (50% cassava flour +50% sweet potato powder) (329.44 ºC), on contrary, the peak gelatinization temperature which was only 96.49 ºC in control yellow corn flour flowed by 94.17 was observed in the peak 1 in F5 (100% cassava flour) sample, compared to the other tested samples.

The conclusion temperature (T_c) of all tested samples ranged between 121.46ºC in p1 in sample F2 (75% sweet potato powder +25% cassavas flour) to 369.43 ºC in F3 (50% sweet potato powder +50% cassavas flour) and exhibited a little variation a mong these samples

The gelatinization temperature (Rt) of the tested samples was ranged from 10.67 to 112.2 ºC. Furthermore, Rt were broadest (101.19 and 102.16 ºC for peak 1 in F4 (cassava 100%) and F1 (100% sweet potato powder) samples, respectively, it could be attributed to the irregularly shaped and cuboidal starch granules. This finding was in agreement with the scientific view of Athawale and Lele, (2000) who found that the main decomposition peak of starch was around 300 ºC in thermal studies on granular maize starch. The lowest values of Rt were recorded as 10.67 and13.58 ºC for peak 2 in both F5 and control samples, respectively.

The ΔH value of gelatinization of tested sample was higher (93.92 and 93.90 mcal/mg) in F4 and F2, respectively, and the lowest ΔH value (1.17 mcal/mg) was in the peak 2 in F1, compared to the other tested samples.

Table 6: Differential Scanning Calorimetry (DSC) of different tested samples

Peak	T_o (°C)	Transition Temp.		ΔH	PHI	R_t
		T_p(°C)	T_c (°C)			
			Control			
1	35.93	96.49	143.49	87.38	1.44287	107.56
2	284.37	278.67	270.79	1.54	0.27018	13.58
3	284.37	294.20	313.99	14.17	1.44151	29.62
			F1			
1	38.23	89.58	140.39	111.81	3.91218	102.16
2	287.02	276.62	271.15	1.17	0.1125	15.87
3	314.56	325.61	368.96	20.85	1.88688	54.4
			F2			
1	32.04	78.52	121.46	93.90	2.02022	89.42
2	270.90	279.49	287.19	3.51	0.40861	16.29
3	293.39	303.68	316.23	18.23	1.77162	22.84
4	319.42	328.03	356.07	10.33	1.19977	36.65
			F3			
1	40.10	86.37	146.45	127.60	2.75773	105.9
2	269.18	277.63	284.52	2.54	0.30059	15.34
3	284.52	294.45	313.81	20.98	2.11279	29.29
4	316.25	329.44	369.43	28.72	2.17741	53.18
			F4			
1	42.41	90.65	143.60	93.92	1.94693	101.19
2	289.29	278.54	267.91	3.48	0.32312	21.38
3	314.85	323.79	353.79	10.70	1.19687	38.94
			F5			
1	32.86	94.17	145.06	138.55	2.25983	112.2
2	272.21	279.53	282.88	1.41	0.19262	10.67
3	287.86	295.55	313.28	17.19	2.23537	25.42
4	317.02	331.47	362.01	24.10	1.66782	44.99

T_o = onset temperature, T_p = peak temperature, Tc = conclusion temperature, R_t = gelatinization range ($T_c - T_o$); ΔH_{gel}= enthalpy of gelatinization (dwb, based on dry weight basis of flour), PHI = peak height index $\Delta H_{gel}/((T_p - T_o)$.

3.5. Thermogravimetric Analysis (TGA)

Thermogravimetric Analysis (TGA) measures change in weight and /or rate of change in weight (derivative thermogravimetric analysis (DTG). TGA is a type of testing that is performed on samples to determine changes in weight in relation to change in temperature. TGA has proved to be a suitable method to investigate the thermal stability of polymeric system. The knowledge of both degradation and made of decomposition under the influence of heat is highly recommended in the processing optimization. The threshold decomposition temperature gives an indication of the highest processing temperature that can be used, whereas the study of the kinetics of the different decomposition processes may help in the identification of the degradation mechanisms. Perhaps this technique may be exploited less than DSC in the food investigations, it measures the change of weight in sample during heating or while holding at a constant temperature and primary used to determine the composition of materials and to predict their thermal stability at temperatures up to 600 °C. The technique can characterize materials that exhibit weight loss due to decomposition and /or oxidation as well as dehydration.

The profile of the thermal decomposition of the sample's characteristics with three or four events of thermal decomposition could be illustrated in Table (7). The thermogravimetric curves of the tested samples presented the first event of the thermal decomposition at temperature intervals from 63.28 to 103.5ºC for F1 (100% sweet potato powder) and F5 (100% cassavas flour), respectively.

The percent weight loss in the third stage in the tested samples, ranged from 296.64 ºC in F1 (100% sweet potato powder) to 303.07 ºC in control sample. This stage shows the highest level of loss during decom position. While the F4 (25% sweet potato powder +75% cassavas flour) and F5 (100% cassavas flour) have 4 stages. The F1 (100% sweet potato powder) sample recorded the highest weight loss was 81.214 at 296.64 ºC in stage 3 while the F5 (100% cassavas flour) showed the smallest weight loss (53.28 at 298.96 ºC) at the same stage (stage 3).

The tested sample showed the residue at 600 ºC from 12.67 in F3 (50% sweet potato powder +50% cassavas flour) to 5.35 in F1 (100% sweet potato powder). On the other hand, the samples control (100% yellow Corn flour) and F4 (25% sweet potato powder +75% cassavas flour) come into view approximately12.5 % as seen in Table (7), while the F5 (100% cassavas flour) shows 7.93 %

These results suggest that it is likely, in the case of different investigated samples, that it is the degree of crystallization, rather than granule size, that has the more important impact on thermal properties (Fujita *et al.,* 1998).

Table 7: Thermogravimetric (TGA) data of different powder samples

Stage	Temperature (°C)	Weight %	
	Peak (T_p)	Loss during decom.stages	Residue at 600 ºC
		Control	
1	71.53	7.18	
2	195.4	2.94	12.43
3	303.07	77.43	
		F1	
1	63.28	8.328	
2	202.66	4.987	5.35
3	296.64	81.214	
		F2	
1	66.53	6.956	
2	199.94	5.502	12.67
3	300.2	74.743	
		F3	
1	67.15	8.524	
2	199.79	3.530	10.3
3	302.45	78.239	
		F4	
1	68.46	8.297	
2	204.14	5.238	12.51
3	300.52	57.569	
4	500.2	16.165	
		F5	
1	103.5	8.234	
2	204.42	7.346	7.93
3	298.96	53.28	
4	440.5	20.79	

Sensory Evaluation of the of the Prepared Crackers

The preference for the products, in terms of the sensory parameters used in assessing the product. Sensory evaluation is a unique discipline that makes use of experimental design and statistical analysis concepts to human senses, with the aim of evaluating consumer products. The mean scores of sensory attributes of the crackers are given in Table 8.

Means of sensory evaluation of cracker prepared from corn flour and cassava powder and sweet potato powder replaced by different levels of cassava flour presented in Table (8). Scores for appearance presented the highest value for samples with an increase in cassava flour substitution than sweet potato powder. The results showed also a decrease in the color scores of crackers by increasing of cassava addition levels from in control to 100% cassava flour while the F1sample (100% sweet potato powder) shows closed value to the control sample, the taste score also, showed an almost the same control sample and F5 (100% cassava flour) values, compared to F1(100% sweet potatoes) and F2 (75%sweet potato powder +25 cassava flour) which had the lowest value of the tasted. The texture of the crackers produced from 100% cassava flour obtained the highest grade, compared with the F1 sample (100% sweet potato powder) showed the lowest value, while the treatment F2 (25% cassava flour + 75 sweet potato powder), F3 (50% Cassava flour + 50 sweet potato powder) and F4 (75% cassava flour + 25 sweet potato powder) showed the same value and a lowest value than the control sample. The crispiness scores were increased with the increasing of cassava flour and the highest value was found in control sample whilst F1 sample (100% sweet potato powder) showed the lowest value of crispiness and was decreased when add sweet potato powder. Total scores showed an increase in sample F5 (100% cassava flour) nevertheless F1sample (100% sweet potato powder) showed the lowest value in total scores compeer to control sample. These results are in accordance with Huang and Miskelly (2016).

Table 8: Sensory Evaluation of the of the Prepared Crackers

	Control	F1	F2	F3	F4	F5
Appearance (15)	14.4 ^{a} ±1.02	11.6 ^{c} ± 1.30	11.7 ^{c} ± 0.72	12.2 ^{b} ±0.82	12.6 ^{b} ± 0.52	13.6 ^{a} ±0.82
Color (15)	14.0 ^{a} ±0.32	13.4 ^{b} ± 0.69	12.6 ^{c} ± 0.46	12.8 ^{c} ± 0.76	13.1 ^{c} ±0.67	12.5 ^{d} ±0.32
Flavor (15)	15.0 ^{a} ± 0.45	10.6 ^{d} ± 0.68	13.6 ^{d} ± 0.24	12.2 ^{d} ± 0.55	12.0 ^{c} ± 035	11. 6 ^{b} ±0.45
Texture (15)	14.0 ^{a} ±0.86	11.8 ^{d} ± 0.31	12.2 ^{c} ± 0.53	12.0 ^{c} ± 0.94	12.2 ^{c} ± 0.21	13.4 ^{b} ± 0.16
Taste (20)	17.8 ^{a} ± 0.36	16.4 ^{b} ± 0.45	16.2 ^{d} ± 0.47	16.3 ^{d} ± 0.45	17.0 ^{c} ± 0.49	17.3 ^{b} ±0.37
Crispiness (20)	18.0 ^{a} ± 0.48	17.5 ^{c} ± 0.39	16.33 ^{d} ± 0.35	17.2 ^{c} ± 0.46	17.8 ^{b} ± 0.75	18.2 ^{a} ±0.53
Total score (100)	93.2 ^{a} ± 2.14	80.05 ^{f} ± 1.19	82.83 ^{e} ± 1.56	82.7 ^{d} ± 0.96	84.7 ^{c} ± 0.84	86.6 ^{b} ±0.36

*Values are means of ten panelists ±SD.
Values number in the same raw followed by the same letter are not significantly different at $p<0.05$ level.

Reference

AACC, 2002.Approved Method of American Association of Cereal chemists.Approved Methods the AACC published by the American Association of Cereal Chemists.13th edition.Inc.St.Paul, Minnesota, USA

Abass, A.B., W. Awoyale, B. Alenkhe, N. Malu, B.W. Asiru, V. Manyong, and N. Sanginga, 2018. Can food technology innovation change the status of a food security crop? A review of cassava transformation into "bread" in Africa. 34 (1): 87-102. https://doi.org/10.1080/87559129.2016.1239207

Agrahar-Murugkar, D., S. Dwivedi, P. Dixit-Bajpai, and M. Kumar, 2018. Effect of natural fortification with calcium and protein rich ingredients on texture, nutritional quality and sensory acceptance of cookies. Nutrition and Food Science, http:// doi.org/10.1108/nfs-02-2018-0041

Alonso-Gomez, L., A.M. Ni˜no-L´opez, A.M. Romero-Garz´on, P. Pineda-Gomez, A. del Real- Lopez, and M.E. Rodriguez-Garcia, 2016.Physicochemical transformation of cassava starch during fermentation for production of sour starch in Colombia.Starch- St¨arke, 68(11–12): 1139–1147.

AOAC., 2012. AOAC official methods of analysis (18th ed.).Gaithersburg, USA: AOAC international.

Athawale, V. and V. Lele, 2000.Thermal studies on granular maize starch and its copolymers with vinyl monomers.Starch /Stärke , 52:205-213.

Averousa, L. and N. Boquillon, 2004. Biocomposites based on plasticized starch: thermal and mechanical behaviours.Carbohydrate Polymers, 56: 111–122.

Bascuñán, K.A., M.C. Vespa, and M. Araya, 2017.Celiac disease: Understanding the gluten-free diet. Eur. J. Nutr., 56: 449–459.

Batifoulier, F., M.A. Verny, C. Besson, C. Demignê, and C. Rêmêsy, 2005. Determination of thiamine and its phosphate esters in rat tissues analyzed as thiochromes on a RP-amide C_{16} column.J.of Chromatograpy B., 816: 67-72.https://doi.org/10.1016/j.jchromb.2004.11.004

Bedeir, S.A., 2004.Addition of gluten, pentosans, ascorbic acid and milk casein to wheat flour to produce a high-quality bakery product. Ph.D. Thesis, Food Sci. Dep., Fac. of Agric., Moshtohor-Zagazig Univ.

Chen, Z., H.A. Schols, and A.G.J. Voragen, 2003. Physicochemical properties of starches obtained from three different varieties of Chinese sweet potatoes.Journal of Food Science, 68:431- 437.

Ciacci, C., M. Cirillo, R. Cavallaro, and G. Mazzacca, 2002. Long-term follow-up of celiac adults on gluten-free diet: prevalence and correlates of intestinal damage.Digestion, 66(3): 178-185.

Demirkesen, I., 2016. Formulation of chestnut cookies and their rheological and quality characteristics.Journal of Food Quality, 39(4): 264-273. https://doi.org/10.1111/jfq.12209

Dudu, O.E., L. Li, A.B. Oyedeji, S.A. Oyeyinka, and Y. Ma, 2019.Structural andfunctional characteristics of optimised dry-heat-moisture treated cassava flour and starch.International Journal of Biological Macromolecules, 133: 1219–1227.

EL-Bedawy, A.A., E.H. Mansour, A.E. EL-Beltagy, G.A. Zahran, and W. Badrm, 2009. Producing of gluten free biscuits for celiac patients, Minufiya J. Agric. Res., 34 (4):1573-1586

Erbas, M., M. Certel, and M.K. Uslu, 2005. Some chemical properties of white lupin seeds (*Lupinus albus* L.). Food Chemistry, 89(3):341-345.DOI: 10.1016/j.foodchem.2004.02.040

Fujita, S., H. Yamamoto, Y. Sugimoto, N. Morita, and M. Yamamori, 1998.Thermal and Crystalline Properties of Waxy Wheat (*Triticum aestivum* L.) Starch J. Cereal Sci., 27: 1–5.

Gaines, C.S., 1991. Instrumental measurement of the hardness of cookies and crackers Cereal Foods World, 36: 989–996.

Han, J., J.A. Janz, and M. Gerlat, 2010. Development of gluten-free cracker snacks using pulse flours and fractions Food Res. Inter., 43: 627–633. https://doi.org/10.1016/j.foodres.2009.07.015

Haynes, L. and M. Schuenzel, 2011. Flour starch thermal characteristics J. Therm. Anal. Calorim, 106:261–266.

Huang, S. and D. Miskelly, 2016. Optimal ingredients for dough.In: Steamed bread- ingredients, process and quality.Woodhead Publishing (47-63).

Ihediohanm, N.C., 2010. Determination of the glycemic indices of three different cassava granules (Garri) and the effect of fermentation period on their glycemic responses.Pakistan Journal of Nutrition, 10(1):6–9.

James, C.S., 1995. General Food Studies. In: Analytical Chemistry of Foods, Blachie Academic and Professional, London, New York, Tokyo, Chapter, 6:135-146.

Julianti, E., Rusmarilin, H., R. Ridwansyah, and E. Yusraini, 2017. Functional and rehological properties of composite flour from sweet potato, maize, soybean and xanthan gum. J. Saudi Soc. Agric. Sci., 16:171-179. http://dx.doi.org/10.1016/j.jssas.2015.05.005

Kaur, L., N. Singh, and N. Sodhi, 2002. Some properties of potato and their starches.Morphological, thermal and rheological properties of starches. Food Chem., 79: 177–181.

Kweon, M., L. Slade, H. Levine, and D. Gannon, 2014. Cookie-versus-cracker baking- what's the difference? Flour functionality requirements explored by SRC and alveograph. Critical reviews in Food Science and Nutrition, 54: 115-138.

Lee, M.H., M.H. Baek, D.S. Cha, H.J. Park, and S.T. Lim, 2002. Freeze- thaw stability of sweet potato starch gel by polysaccharide gums. Food Hydrocolloids, 16: 345-352.

Lusas, E.W., 2001. Overview. In E.W. Lusas and L.W. Rooney (Eds.), Snack Foods Processing.Boca Raton: CRC Press LLC.

Mian, K.S., S.B. Masood, M.A. Faqir, and N. Haq 2009. Preparation of fiber and mineral enriched defatted rice bran supplemented biscuits Pakis. J. Nutri, 8(5):571–577. DOI: 10.3923/pjn.2009.571.577

Montagnac, J.A., C.R. Davis, and S.A. Tanumihardjo, 2009. Nutritional value of cassava for use as a staple food and recent advances for improvement.Comprehensive Reviews in Food Science and Food Safety, 8(3): 181–194.

Mosha, T.C.E., H.S. Laswai, and I. Tecens, 2000. Nutritional composition and micronutrient states of homemade commercial weaning foods consumed in Tanzania.Plant Foods for Human Nutrition, 55 (3): 185: 205.

Mousia, Z., S. Edherly, S. Pandiella, and C. Webb, 2004. Effect of wheat pearling on flour quality Food Rese. Inten., 37: 449–459

Ogbo, F.C., and Okafor, E.N.2015.The resistant starch content of some cassava based Nigerian foods.Nigerian Food Journal, 33(1): 29–34.

Oladeyebe, A.O., A.A. Oshodi, and A.A. Oladeyebe, 2009. Physicochemical properties of starches of sweetpotato (*Ipomea batata*) and red cocoyam (*Colocasia esculenta*) cormels. Pakistan Journal of Nutrition, 8: 313-315.

O'Shea, N., K.N. Kilcawley, and E. Gallagher, 2017. Aromatic Composition and Physicochemical Characteristics of Crackers Containing Barley Fractions. Cereal Chemistry, 94(3):611-618. https://doi.org/10.1094/CCHEM-10-16-0256-R

Padonou, W., C. Mestres, and M. Offinago, 2005. The quality of boiled cassava roots instrumental characterization and relation ship with physicochemical properties and sensorial properties. Food Chemistry, (89) : 261-270.

Plozza, T., V.C. Trenerry, and D. Caridi, 2012. The simultaneous determination of vitamins A, E and B-carotene in bovine milk by high performance liquid chromatography-ion trap mass spectrometry (HPLC-MSn). Journal of food chemistry, 134(1): 559-563. https://doi.org/10.1016/j.foodchem.2012.02.121

Pramodrao, K.S. and C.S. Riar, 2014. Comparative study of effect of modification with ionic gums and dry heating on the physicochemical characteristic of potato, sweet potato and taro starches. Food Hydrocolloids, 35: 613-619.

Rosell, C.M., F. Barro, C. Sousa, and M.C. Mena, 2014. Cereals for developing gluten-free products and analytical tools for gluten detection. Journal of Cereal Science, 59: 354-364.

Singh P., A. Arora, T.A. Strand, D.A. Leffler, C. Catassi, P.H. Green, C.P. Kelly, V. Ahuja and G.K. Makharia 2018. Global Prevalence of Celiac Disease: Systematic Review and Meta-analysis, Hepatology, June: 823-836. https://doi.org/10.1016/j.cgh.2017.06.037

Tetchi, F.A., A.R. Sabate, G.N. Amani, and P. Colonna, 2007. Molecular and physicochemical characterisation of starches from yam, cocoyam, cassava, sweet potato and ginger produced in the Ivory Coast. Journal of the Science of Food and Agriculture, 87: 1906- 1916.

Tunick, M.H., C.I. Onwulata, A.E. Thomas, J.G. Phillips, S. Mukhopadhyay, S. Sheen, C.K. Liu, N. Latona, M.R. Pimentel, and P.H. Cooke, 2013.Critical evaluation of crispy and crunchy textures: A review, Int. J. Food Prop., 16:949-963. https://doi.org/10.1080/10942912.2011.573116

Ugwuona, F.U., U.B. Ejinkeonye, and H. Ibrahim, 2017. Effect of Added Sesame Seed on Quality Characteristics of Wheat Bread JHER, 24(2):1– 12.

Usal, H., N. Bilgicali, A. Elgun, S. Ibanoglu, E. Nurherken, and M. Kursat, 2007. Effect of dietary fiber and xylanase enzyme addition on the selected properties of wire cut cookies.Journal of Food Engineering, (78): 1074 - 1078.

Vasanthan, T. and R. Bhatty, 1996. Physicochemical properties of small and large granule starches of waxy, regular, and high amylase barleys Cereal Chem*.*, 73: 199–207.