IJABR, VOL.7 (2) 2017: 272-277 ISSN 2250 – 3579

INTERNATIONAL JOURNAL OF ADVANCED BIOLOGICAL RESEARCH

PHYSICO-CHEMICAL PROPERTIES AND HYDRATION BEHAVIOUR OF SORGHUM AND MAIZE FOR DEVELOPMENT OF CEREAL FLAKES

[a*]Satish Kumar, [a]Ashok Kumar, [a]Sanoj Kumar, [b]Prem Prakash
[a]Department of Agricultural Engineering, Bihar Agricultural College, Sabour, Bhagalpur, Bihar
[b]Department of Food Science and Post harvest Technology, Bihar Agricultural College, Sabour, Bhagalpur, Bihar-813210
Correspondence: *Assistant Professor, Department of Agricultural Engineering, Bihar Agricultural College, Sabour, Bhagalpur (Bihar) – 813210
BAU communication no. - 234
*Corresponding author e-mail: skumarbau@gmail.com

ABSTRACT
Physico-chemical properties along with hydration behavior of cereals play an important role for the development of cereal flakes. Some of the physic-chemical properties along with hydration behavior of sorghum and maize seeds were determined during the investigation. Moisture content of sorghum and maize was found to be in the range of 9.82 to 82.10 (%, w.b) and 9.12 to 79.9 (%, w.b) respectively. The average length, sphericity, porosity and hardness were found 2.85 & 4.17 mm, 71.25 % & 62.60 %, 0.07 & 0.42 and 6.26 Kg & 8.25 Kg for Sorghum & Maize respectively. Whereas ash content, fat content, protein content, crude fibre were found 1.033 & 1.2, 7.75 & 9.2, 2.25 & 1.46 g/100g for sorghum and maize respectively.

KEYWORDS: Hydration, maize, sorghum, flaking, sphericity, hardness.

INTRODUCTION

Cereal is a cultivated grass, such as wheat, corn, rice, oats and sorghum, which produces an edible seed (grain or fruit) and they are particularly important to humans because of their role as staple food crops in many areas of the world. Cereals are also used to produce animal feed, oils, starch, flour, sugar, syrup, processed foods, malt, alcoholic beverages, gluten and renewable energy. In more affluent countries, many varieties of grains and whole grains, processed ready-to eat (RTE) breakfast cereals, and cereal bars and so forth are consumed. Approximately 50% of the world's calories are provided by rice, wheat and maize, but in many parts of Africa and Asia, people rely mainly on grains such as sorghum or millet.

Sorghum occupies 5th place in the world in the production of cereals with about 65 millions tones/year and USA is the major producer of this. Sorghum (sorghum bicolor) is an important food crop of arid and semi arid regions of the world. In semi arid tropical countries like India, annual production is about 20 millions tones (Nagappa *et al*., 1996) almost all of which is used for food in the regions of production. Sorghum is a genus with many species and subspecies, and there are several types of sorghum, including grain sorghums, grass sorghums (for pasture and hay), sweet sorghums (for syrups), and Broomcorn. Maize (*Zea mays* L.) also called corn is the most important cereals crops in the world, grown over an area of 132 million hectare and second highest produced cereal grain crop of the world with the total annual production of 570 million tonnes (Watson and Ramstad, 1987). India has an average area of about 5.99 million hectares under coarse cereals (*i.e*. sorghum, ragi, jowar maize and bajra) cultivation. Maize alone accounted for much larger production of 15.35 million tonnes in 2006-07. Utter Pradesh, Madhya Pradesh, Bihar, Rajasthan, Punjab are the leading states in India growing maize on large scale. Jammu and Kashmir, Andhra Pradesh, Gujarat and Himachal Pradesh also grow considerable amount of maize. Maize is now being accepted as staple diet and its demand is increasing, consumption of maize in the form of various types of traditional foods such as bread, porridge, steamed products, beverages and snacks. In India, maize grains are roasted and ground to prepare a traditional food Sattu (roasted grain flour) which is consumed as a breakfast item by mixing either water or milk with salt or sugar. Maize is also ground whole to make flour and is consumed in the form of chapatti (unleavened Indian bread) at rural level.

Flaking is a relatively simple process, consisting in its most elemental form of cooking fragments of cereal grains (or sometimes whole grains), flattering the soft particles between rollers, and toasting the resultant flake at high temperatures. Apparently the first commercial production of such a food occurred around the turn of the century when whole wheat flakes in a barn behind the Battle Creek Sanitarium (J. H. Kellogg and W. H. Kellogg, 1970). Many complications have been introduced into the process since that time in attempts to improve the flavor and the efficiency of operations, and to increase the uniformity of flake size and appearance which so desirable to the manufacturer and perhaps to the consumer. Flakes owe their popularity with consumers to their crisp but friable texture, to their sweet but rather bland flavor, and to the ease with which a portion may be readied for consumption. In the basic processing steps, the raw material undergoes the following changes; the starch is gelatinized and probably slightly hydrolyzed, the particle undergoes a browning reaction due probably to interaction of proteins and sugars, enzymatic reaction stopped, rendering the final product more stable, dextrinization and caramelization of the sugars occur as a result of the high temp in the roasting ovens, the flakes become crisp as a result of the reduction of its moisture content to a very low level.

Mainly puffed and flaked products are famous as ready to eat breakfast cereal and in some literature it has been found that cereal puffs may be tastier than flakes but it has been also found that flakes are healthier than puffs. However, world population increasing & due to fast lifestyle human being, dependence on ready to eat breakfast cereals is more because it provides all nutrition for human health, also sorghum provides all nutrition if enriched. There are many research work on the development of rice flakes, wheat flakes & corn flakes, but there is no work on the development of sorghum flakes.

MATERIALS & METHODS

The Sorghum and Maize were used in the investigation which was procured from a local market of Bhagalpur in the state of Bihar (India) then cleaned manually to remove all foreign matters such as dust, dirty, stones.

Physical properties of sorghum & maize cereal

Size and shape indices

The sorghum and Maize cereal size, in terms of the three principal axial dimensions, that is length, breadth and thickness as the grain shape tester (K200, Japan) with an accuracy of 0.01 mm. The seed shape was also determined in terms of its geometric mean diameter, sphericity, roundness and aspect ratio. The geometric mean diameter (D_p) of the seed was calculated by using the following relationship (Mohsenin, 1970):

$$D_p = (LWT)^{1/3} \tag{1}$$

The degree of sphericity (Φ) was calculated using the following formula as described by (Mohsenin, 1970):

$$\Phi = \frac{(LWT)^{1/3}}{L} \times 100 \tag{2}$$

Where L is the length, W is the width and T is the thickness.

True and bulk densities

The true density of a cereal defined as the ratio of the mass of a sample of a cereal to the solid volume occupied by the sample. The true density of sorghum cereal determined by pycnometer with the help of flow of N_2 gas.

$$\text{Vsample} = \frac{\text{Vcell}-\text{Vexp}}{(\frac{P1}{P2})} \tag{3}$$

$$\text{True Density} = \frac{\text{Wsample}}{\text{Vsample}} \tag{4}$$

Bulk density is the ratio of the mass of a sample of seed to its total volume. The bulk density was determined using the mass volume relationship (Mohsenin, 1970) by filling an empty iron container of predetermined volume and tare weight with the seeds by pouring from a constant height, striking of the top level and weighing.

$$\text{Bulk Density} = \frac{\text{Mass}}{\text{Volume}} \tag{5}$$

Porosity (£)

The porosity (£) of bulk cereal was computed from the values of true density and bulk density using the relationship given by Mohsenin (1970) as follows:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \tag{6}$$

Where, ρ_t = True density ρ_b = Bulk density

Hardness

Compressive strength of cereals grain was considered an important mechanical property in relation to seed breakage during extraction. The compressive strength of the cereal grain was measured by using Instron Universal Testing machine. The Instron machine consist of a rectangular plate, flat, clamps and digital display unit. The load cell was attached with the help of a flat and clamps to the vertically moving upper cross-head of the Instron machine. The base of the Instron machine was used as the base for placement of sorghum cereal.

Angle of repose

To determine the emptying or dynamic angle of repose, a sunmica box of 300 × 300 × 300 mm, having a removable front panel was used. The box was filled with the sample, and then the front panel was quickly removed, allowing the seeds to flow and assume a natural slope. The angle of repose was calculated from the measurement of the maximum depth of the free surface of the sample and the diameter of the heap formed outside the container. All these experiments were replicated five times, unless stated otherwise, and the average values are reported at the set moisture content.

Proximate Analysis of maize and sorghum cereal

The proximate analysis gives useful information about the material, particularly from nutritional and bio-chemical point of view. Following proximate constituents were analyzed.

Initial Moisture content

The moisture content of raw sorghum and maize was determined by standard oven drying method. About 10 g of representative sample was weighed and kept in oven at 105 ± 2^0 C for 24 hours. The dried samples were cooled in desicator to room temperature and then weighed using electronic balance and the moisture content of the material was expressed in wet and dry basis (Ranganna, 2002).

Ash content

The ash content of a foodstuff or cereal grain represents inorganic residue remaining after destruction of organic matter. It may not necessarily be exactly equivalent to the mineral matter as some losses may occur due to volatilization. Taking tare weight of three silica dishes (7-8 cm dia.). Weigh 2 gm of sample into each. Now ignite the dish and the contents on a Bunsen burner. Ash the material at not more than 525 ^{0}C for 4 to 6 hrs. Now cool the dishes and weigh. The difference in the weights gives the total ash content and is represented as percentage.

Fat content

Fat soluble material in a food or cereal is extracted from an oven dried sample using a soxhlet extraction apparatus**.** The ether is evaporated and the residue weighed. The ether extract or crude fat of a food represents, besides the true fat (triglycerides), other materials such as phospholipids, sterols, essential oils, fat soluble pigments, etc. extractable with ether. Water-soluble materials are not extracted since the sample has been thoroughly dried prior to extraction with anhydrous ether.

$$(\%)\text{Fat} = \frac{\text{Wt.of the fat soluble material}}{\text{Wt.of the sample}} \times 100 \qquad (7)$$

Protein content

Determination of protein content or Nitrogen content is estimated by Kjeldahl method which is based on the determination of the amount of reduced nitrogen (NH_2 and NH) present in the sample. The various nitrogenous compounds are converted into ammonium sulphate by boiling with conc. H_2SO_4. The ammonium sulphate formed is decomposed with an alkali (NaOH), and the ammonia liberated is absorbed in excess of neutral boric acid solution and titrated with standard acid.

$$N_2\,(\%) = \frac{(\text{sample titre - blank titre}) \times \text{N of HCl} \times 14 \times \text{vol. made up} \times 100}{(\text{Aliqout}) \times \text{Wt. of the sample taken} \times 1000}$$

$$\text{Protein}\,(\%) = N_2\,(\%) \times 6.25 \qquad (8)$$

Crude fibre content

Crude fibre consists largely of cellulose lignin (97 %) plus some mineral matter. It represents only 60-80 % of the cellulose and 4-6 % of lignin. Commonly used in quality & quantity. Extract 2g of ground material with ether to remove fat (Initial Boiling temp. 35.38 ^{0}C and final temp. 52 ^{0}C). After extraction with ether boil 2g of dried material with 200 ml of H_2SO_4 for 30 min. with bumping chips. Then filter through muslin and wash with boiling water until washing are no longer acidic. Then boil with 200 ml of NaOH solution for 30 min. Filter through muslin cloth and wash with 25 ml of boiling 1.25 % H_2SO_4 3.25 ml portion of H_2O and 25 ml OH. Remove the residue and transfer to ashing dish (w_1). Drying the residue for 2 hour at 130 ^{0}C. Cool the dish in desicator and weigh (w_2) and ignite it for 30 min. at 600 ^{0}C then cool in a desicator and weigh (w_3).

$$(\%)\text{ Crude Fibre} = \frac{\{(w2 - w1) - (w3 - w1)\}}{\text{Wt.of the sample}} \times 100 \qquad (9)$$

Hydration Techniques

Several hydration techniques were investigated for determining hydration behavior of the corn which increase the hardness of the grains by absorbing maximum amount of water and also caused minimum stress cracks in the kernels.

The hydration techniques viz. water spray, steam treatment, steaming-water soaking and soaking in water was investigated for determining hydration behavior of maize with minimum stress cracks development and maximum water absorption.

Soaking in water

The techniques which we used for the present research was soaking of kernels in to water. The experimental kernels were visually inspected for relatively uniformed weight. Then samples of corn & sorghum kernels, about 20 g each, were weighed using an electronic balance. Each sample was placed in a flask containing 250 ml of water. The flasks were placed in water bath. Individual flasks were removed from the water bath at 1, 3, 5, 10, 20, 35, 60, 120, 300, 700, 1440 and 1800 min. the kernels were dried using blotting paper to eliminate the surface water. Then they were weighed and the percentage of the moisture content of the sample M, at each interval was determined by following:

$$M = \frac{(m - m_i) + m_i \times IM}{m} \times 100 \qquad (10)$$

Where,
M=moisture content, %
m = mass of the sample at a specified time interval, g
m_i = mass of the sample prior to soaking, g
IM= initial moisture content of the kernels

The experiments were performed at temperature of 30, 40, 50, 60, 70, 80 and 90 ^{o}C.

Hydration characteristics of Sorghum

Clean raw sorghum was soaked at different temperatures in constant temperature water bath, under atmospheric condition, to determine the hydration behaviour of sorghum.

Variables involved

The different variables influencing the hydration characteristics of sorghum and maize were out lined as below:

TABLE1. Different variables influencing the hydration characteristics of sorghum and maize

Independent Variables	Dependent variables
Time (0, 30, 60, 90, 120, 150, 180, 210, 240 min.) Temperature (30, 50, 60, 70 ^{0}C) for Sorghum Temperature (30, 40, 50, 60, 70, 80, 90 ^{0}C) for maize	Hardness

Experimental setup

A constant temperature water bath was used for soaking experimental consist of a water holding chamber with an immersion heating coil for heating the water and a thermostat for control of water temperature. The required temperature can be obtained by adjusting the knob.

Experimental procedure

The soaking test was conducted in an aluminium container. The constant temperature water bath was adjusted to a temperature of 20 ^{0}C higher than the required temperature of soaking. A few gram samples were taken in the container maintaining a grain to water ratio of 1:2

(v/v). For the experiments the water was heated separately to a temperature that when sorghum at room temperature was mixed with water, the desired soaking temperature achieved. The temperature of the mixture was measured by mercury in glass thermometer. The sample was frequently stirred manually for maintaining uniform temperature throughout the soaking medium.

Small sample were taken out with the help of an aluminium ladle at different time interval and it were gently blotted to remove to adhering moisture. The samples were then quickly weighed by an electronic balance. The moisture content of the sample were determined using standard drying air oven method and moisture contents were expressed both in per cent wet and dry basis.

RESULTS & DISCUSSION

Physical properties of sorghum cereal

Physical properties of cereals were carried out in physical properties lab and measure observation has been found. The geometric mean diameter (D_p) of sorghum and maize were found to be 2.85 mm and sphericity (Φ) is 0.7125. The true and bulk densities of sorghum cereal are found to be 753.14 kg/m^3 and 700.50 kg/m^3 respectively. Also porosity is calculated and found to be 0.07. The hardness of the sorghum cereal is found to be 6.2575 Kg. Angle of repose was found to be 16.7^0. Co-efficient of friction at Iron, Al., & Asbestos surfaces was found to be 0.38, 0.38, and 0.41 respectively.

TABLE 2: Physical Properties of Sorghum and Maize

Cereal	Geometric Mean Diameter (mm)	Sphericity (%)	Bulk Density (kg/m^3)	Porosity	Hardness (Kg)	Angle of Repose (%)
Sorghum	2.85	71.25	700.50	0.07	6.2575	16.7^0
Maize	4.17	62.60	765.00	0.42	8.2546	19.3^0

Proximate composition of sorghum

Proximate analysis of sorghum and maize cereals were carried out at FST laboratory and measure observation has been found.

TABLE 3: Proximate composition of Sorghum and Maize

Cereal	M.C (%,w.b)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Crude Fibre (%)
Sorghum	9.82	7.75	0.85	1.033	80.58	2.25
Maize	9.12	9.2	4.6	1.2	73.0	1.46

From above table we can observe that carbohydrate & protein content of sorghum is very quite similar to corn so it provides all nutrition to human.

TABLE 4: Soaking of sorghum at different temperatures

	30 ^{0}C (Room temp.)	50 C	60 C	70 C
Time (min.)	M.C (% w.b)	M.C (% w.b)	M.C (%w.b)	M.C (%w.b)
0	9.82	9.82	9.82	9.82
30	17.85	20.76	24.46	28.45
60	20.65	24.32	30.52	36.62
90	23.45	29.45	37.45	43.75
120	26.12	32.32	44.64	51.05
150	28.92	36.45	50.75	59.12
180	31.34	40.41	54.64	63.25
210	34.27	44.14	59.12	70.74
240	38.67	48.52	64.32	78.46

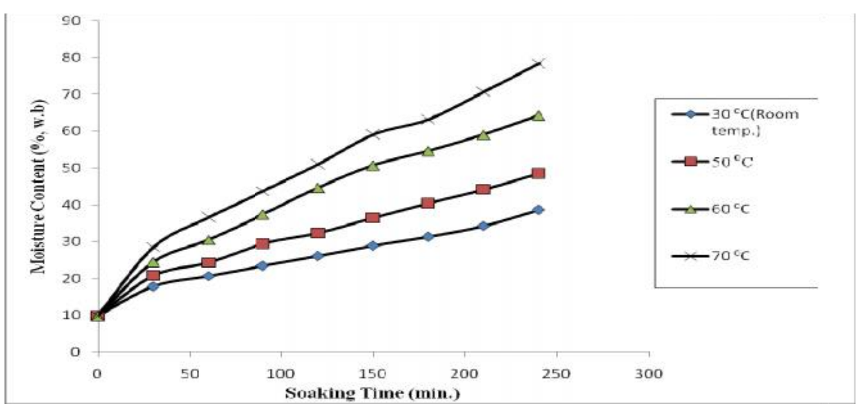

FIGURE1- Hydration characteristics of sorghum at different temperatures

Soaking characteristics of sorghum

The variation in moisture content of sorghum with soaking time at different soaking temperature is shown in Fig 1. There was rapid rate of moisture uptake during initial phase of soaking. The moisture uptake rate increased with increase in soaking temperature. During hot soaking energy provided in the form of heat weakness the granular structure by disrupting the hydrogen bonds; therefore more surface area is available by starch granular for water absorption. This permits further hydration and irreversible swelling.

TABLE 5: Hardness of sorghum at different time & temperatures

Soaking time (min)	Hardness at 50ºC(kg)	Hardness at 60ºC (kg)	Hardness at 70ºC (kg)
0	5.67	5.25	5.15
15	5.45	5.46	5.56
30	5.29	5.35	5.05
45	5.08	5.20	6.09
60	6.25	5.35	6.25
75	5.65	5.85	5.64
90	5.75	5.76	5.96
105	5.46	5.98	5.76
120	6.15	6.05	5.33
135	5.47	6.23	5.46

TABLE 6- Hydration behavior of corn at different temperature and time combinations

Time (min)	Temperature °C						
	30	40	50	60	70	80	90
0	12.2	12.2	12.2	12.2	12.2	12.2	12.2
1	13.5	14.4	15.7	16.5	18	18.7	19.8
3	15.6	16.8	17.9	19.4	20.7	22.1	23.4
5	16	18.6	19.6	21	23.2	24.3	25.5
10	17	20.2	21.4	22.7	24.1	26.3	28.7
20	20	21.3	22.6	23.5	26.4	28.6	29.7
35	21	22.3	24.3	25.4	29.6	30.1	34
60	23	24.5	25.16	28.4	32.4	34	39.4
120	25	26.8	29.12	32	36.4	40.1	45
300	29.2	32	37.5	39	47.6	52	59
700	35.6	40	47	50.1	58.8	68.6	72
1140	36.5	40.4	48	52	63.5	72.1	77.8
1440	36.7	40.6	48.2	52.4	63.8	72.4	79.5
1800	36.8	39.8	48.6	51.9	63.4	72.8	79.9

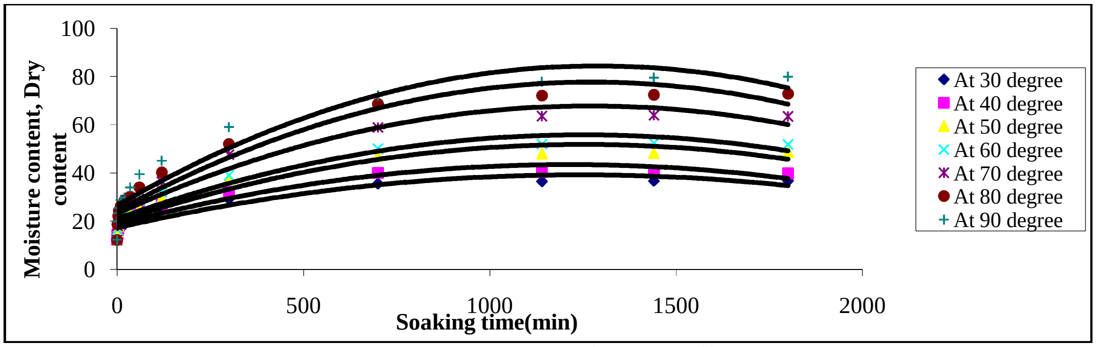

FIGURE 2. Hydration characteristics of corn at different temperatures.

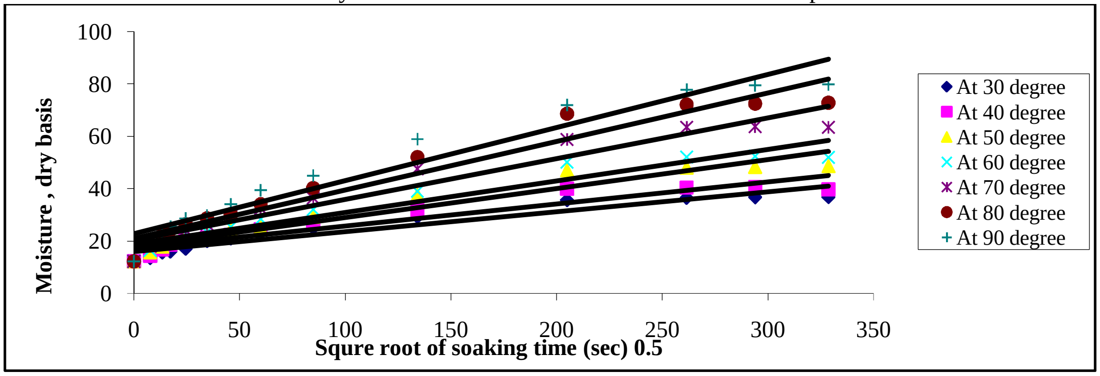

FIGURE 3. Relationship between square root of soaking time and moisture uptake.

Fig. 1 shows that the gradual increase in the rate of water absorption up to 300 min and after 300 min the curve becomes linear for water absorption. However, for the treatments above 60° C the slope is slightly steeper indicating that in addition to simple water diffusion, some water is also utilized for the gelatinization of starch. Stress crack kernel were observed at a soaking temperature of 80° C and 90° C this indicate that during hot soaking heat weakens the starch granules by disrupting the hydrogen bond, therefore more surface area is available by the starch granules for the water absorption.

CONCLUSION

The following conclusions were drawn for this investigation on physic-chemical properties and hydration behavior of sorghum and maize seeds. Hydration Characteristics of corn investigated at different temperature of 30, 40, 50, 60, 70, 80, and 90 ^{0}C at time period 1, 3, 5, 10, 20, 35, 60, 120, 300, 700, 1440 and 1800 min. and found that with increase steeping water temperature, the amounts of water absorbed is increased. Increased in the rate of water absorption with the increase in the water temperature also reported by (Sayar et al., 2001). The high rate of water absorption during the initial stages of soaking is generally attributed to the natural capillaries present in the surface of the kernels which can be explained by the diffusion phenomenon. And also found that the gradual increase in the rate of water absorption up to 300 min after 300 min the curve becomes linear for water absorption.

REFERENCES

Aboubacar, A. & Hamaker, B.R. (1999) Physicochemical properties of flours that relate to sorghum couscous quality. Cereal Chemistry, **76**: 308–313.

Bhattacharya, S. and Sumithra, B. (2008) Toasting of corn flakes: Product characteristics as a function of processing conditions, Journal of Food Engineering, **88**:419-428.

Chaunier, L., Valle, G.D. and Lourdin, D. (2007) Relationships between texture, mechanical properties and structure of cornflakes. Food Research International, **40**: 493–503.

Chaunier, L., Courcoux, P., Della V.G. and Lourdin, D. (2005) Physical and sensory evaluation of cornflakes crispness. Journal of Texture Studies, **36**: 93–138.

Georget, D.M.R., Parker, R. and Smith, A.C. (1994) A study of the effect of the water content on compaction behaviour of Breakfast cereal flakes. Powder technology. **89**:189-195.

Kulamarva, A. G., Sosle, V. R., Raghavan, G.S.V. (2009) Nutritional and Rheological Properties of Sorghum. International Journal of Food Properties, **12**: 55–69.

Lee, W.J., Pedersen, J.F. and Shelton, D.R. (2002**)** Relationship of Sorghum kernel size to physiochemical, milling, pasting, and cooking properties. Food Research International, **35**: 643–649.

Levine, L., Campanella, O.H., Okos, M.R. and Ross, K. (2004) Observations on physicochemical changes with flaking. Cereal Foods World, **19**(2): 67–69.

Mwithiga, G. and Sifuna, M.M. (2006) Effect of moisture content on the physical properties of three varieties of sorghum seeds. Journal of Food Engineering, **75**:480-486.

Olayinko, O.O. and Adebowale, K.O. (2008) Effect of heat–moisture treatment on physicochemical properties of white sorghum starch. Journal of Food Hydrocolloids, **22**:225-230.

Rao, U.J.S.P., Vatsala, C.N. and Rao, P.H. (2002) Changes in protein characteristics during the processing of wheat into flakes. Journal of Eur Food Res Technol, **215**:322–326.

Rooney, L.W., & Sullins, R.D. (1970) Chemical, physical and morphological properties of diploid and tetraploid Sorghum bicolor (L.) Moench kernels. Crop Science, **10**: 97–99.

Sevim Sagol, Mahir Turhan, Sedat Sayar (2001) A potential method for determining in situ gelatinization temperature of starch using initial water transfer rate in whole cereals. Journal of Food Engineering. **76**: 427-432.

Singh, P.P., Maier D.E., Okos, M.R., Cattanach, E., and Trumble, K.P. (1999) Effects of Physical Properties and Operating Parameters on Soybean Flaking. Paper no. J9042 in JAOCS **76**: 981–987.

Watson, S.A. and Ramstad, P. E. (1987) Corn: Chemistry and Technology. American Association of cereal chemists, St. Paul, Minnesota, USA

Whalen, P. J. (1999) Measuring process effects in ready-to-eat breakfast cereals. Cereal Foods World, **44**: 407–412.

Wills, R.B.H. and Ali, M.R. (1983) Effect of grain size on dehulling of sorghum. Cereal Chemistry, **60**: 12–14.