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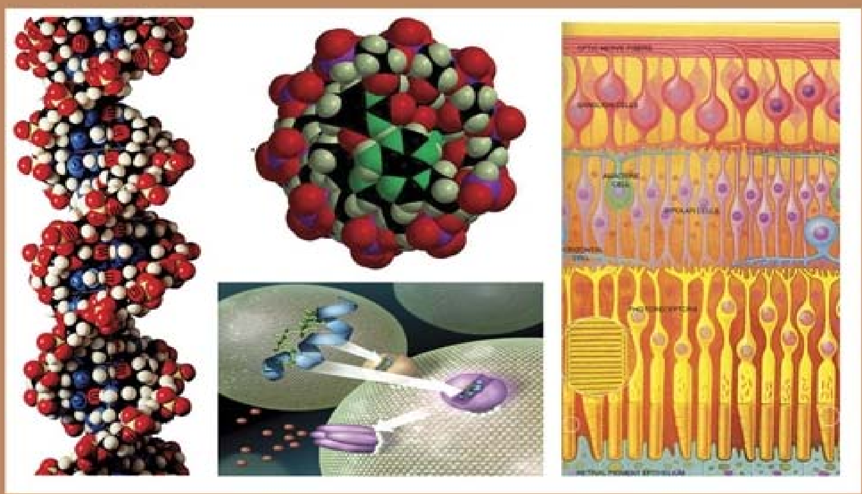

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Some Sorghum Milling Techniques versus Flour Quality

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ABSTRACT

Tabat a Sudanese sorghum cultivar was collected from local Khartoum market season 2009; three samples were cleaned and prepared for milling. A commercial decorticator was used to decorticate 10% from Sample A and 5% from Sample B, Sample C was whole grain. The three samples were milled on commercial stone mill and a laboratory disc mill. The mills were set to produce the finest and coarsest possible flours. Milled stocks were analyzed to examine some milling quality parameters: moisture and protein losses, color, ash content and granularity. Fine sorghum semolina was evaluated as wheat flour improver ingredient carrier. When sorghum and wheat fine semolina were compared as wheat flour improver carrier no significant differences were observed on farinograph results. It can be concluded that with suitable mill adjustment and suitable sifting media stone and disc mills can produce wide range of sorghum products: flour fine semolina and coarse semolina for diverse uses, when a decorticated or partially decorticated sorghum is used.

INTRODUCTION

Sorghum bicolor (L.) Moench is the second most important cereal food, after maize, for millions of people living in the semi arid and sub-tropical regions of Africa (Taylor2003). It is an important element to Sudanese diet as a source of calories and proteins. It is consumed in a number of ways, most notably as a flat bread or pancake known as "*kisra*" and as a pudding known as "*acida*". Large quantities of sorghum, particularly in the western and southern states are made into local beer known as "*marisa*" (Hamid2010).Annual sorghum production ranges between 3.4to 4.2 million tons which accounts for 20% of Africa's production and about 10% of world production (Ali 2012), (Noureldin*et al.* 2012). Sorghum ranks first among cereals consumed in the Sudan; cereals per capita were estimated at 140 kg/annum, 90 kg of which is sorghum, 10 kg millet and 40 kg wheat (Ismail2010).

Most of This sorghum is milled on stone mills; decorticated or whole depending on consumer preference, since most of the stone mills are operated as customer mills. In the capital and big towns most of the sorghum is decorticated. Little sorghum is milled on commercial mills. Very little sorghum is milled using traditional pestle and mortar for decortication and saddle stones for milling.

Many trials of sorghum milling techniques have been examined: roller milling after conditioning with the same technique of wheat milling, or decortication then milling on rollers mill (Merwet *et al*. 2005),(Iva 2011). Decortication used for rice and parley also been used for sorghum it is reported to produce meals that contains 25% less fat, 10% less crude fiber and 15% less ash than manual hand pounding, and that the meal has three months shelf life,(Gomez 1993),(Pertin 1977), (Bassey and Schmidt 1989).

(Beshata *et al*. 2006)reported that the most common and widely used type of commercial milling plants in Africa are hammer and stone mills, with capacities of 100-1800 kg/hr and 25-1200 kg /hr respectively. Decortication and hammer milling is the common industrial milling in South Africa. However the main techniques of milling sorghum into flour :either to decorticate or use as whole meal milled on hammer or stone mill or on roller mill in the same or alike technique used for wheat milling. The common application in the Sudan is decorticating and then milling on stone mills. Stone is unlike hammer and roller milling where milled stocks have a controlled granule size. Stone milling fineness depends on the miller experience and stones corrugation or flutes condition. The decortication of sorghum grains reported to decrease moisture, ash, fat, crude protein, iron and phosphorous content (Abdelghafor *et al*. 2013).

Milling quality differs according to technique used. According to (Wingfield1983), the milling quality is measured by: flour yield, freedom of the flour from impurities, as well as flexibility of a mill to produce wide range of products, adaptability of the mill to handle different types of grains and ability of the mill to minimize protein loss from grain to flour (protein recovery). Reviewing the sorghum milling literature we did not find much studies focusing on sorghum semolina. The quality of pasta is highly related to the quality of raw material and also depends on the milling process. In addition to satisfactory agronomic characteristics, the good milling quality is required from sorghum grains in order to provide acceptable industrial flour for the pasta industry (Miche *et al*.1977). A lower extraction rate may significantly improve the pasta appearance. Milling fractions of less than 1% ash content and 1% lipid content are preferred for pasta and may be obtained by preliminary dehulling with a sorghum mill (Perten 1977). However the semolina produced in this study was compared to general purpose wheat semolina from local market of Khartoum for comparing color. Unlike wheat, sorghum flour does not contain gluten. This makes it a suitable alternative food for people with wheat gluten allergies. It is not modified genetically and can be used for products that are labeled as non-genetically engineered products. The objectives of this Study were to 1- compare between milling quality of sorghum milled by different techniques 2- to produce fine and coarse semolina and to evaluate their quality and yield 3- to study the effect of fine sorghum semolina on wheat flour quality particularly farinograph and color when the sorghum semolina is used as improver filler.

MATERIALS AND METHODS

Grain

Tabat a Sudanese sorghum white cultivar was collected from local Khartoum market season 2009. With 8.4 moisture, 10.4 % protein content, 27g TKW.

Cleaning and decortications

The grain was manually cleaned from impurities by winnowing and stones were picked out. A commercial abrasive decorticator (Type 65 NS-33, 1400 rpm) was used to extract 10% (Sample A), 5% (sample B) and (sample C)was the whole grain.

Milling

The three samples were milled on commercial stone mill (locally made in Sudan, Omdurman, industrial area workshops) and on Buhler disc mill type Bühler-Miag MLI-204 grinder Bühler AG,(Gupfenstrasse 5 9240 Uzwil Switzerland).The mills were set to produce the finest and the coarsest possible flours. Flour samples were collected mixed thoroughly, sealed into plastic bags and kept at 4°C for analysis.

Moisture, Protein and Ash content

Perten NIR flour analyzer type 8600/01 calibrated for sorghum was used to determine moisture, protein and ash content of grain and flours. The milling moisture loss was calculated by subtracting the moisture content of the produced flour from the moisture content of the milled grain. Protein recovery was calculated by the following equation:

$$\text{Protein recovery \%} = \frac{\text{Flour Protein} \times 100}{\text{Sorghum protein}}$$

Granulation Test

A laboratory sifter (Antrieb-stechhick type KM10/80-4EVB5S) equipped with sieves of 1000, 700, 530, 355, 280 and 200 microns were used for granulation test. The sample size was 70 gm; the sifting time was 7 minutes, the overtails were weighed. Accumulative overs and throughs were calculated as performed by (Abdelrahim2002).

Color test

"Pekar Flour Color Test was used to evaluate flour and semolina. A simple way for comparing the color of a flour sample with a standard sample. Also called the ""slick"" test, it involves placing a small sample of the test flour on a paddle or other flat surface so that one edge forms a straight line next to a similarly placed sample of a standard flour. Both samples are then slicked with an edge to form a smooth surface that exhibits a distinct line of demarcation between the two flours so that any difference in their color becomes evident. (Baking Business 2014)

Farinograph

Brabender farinograph method was carried out according to AACC 2000. To compare between wheat base flour improved by standard improver (the ingredients carrier is wheat fine semolina) and the same base flour improved by improver whose ingredient carrier is sorghum semolina.

RESULTS AND DISCUSSION

Fine Stone Milling

Flour moisture and moisture milling losses

With reference to Table1, the flour moisture content and milling moisture losses were found to be 4.44, 4.32, 4.01% and 3.47, 3.72, 4.14% for samples A, B and C respectively.

Table 1: Flour moisture content and milling moisture losses.

Grain moisture		flour moisture content				moisture losses			
Sample #	content	fine stone milling	fine disc milling	coarse stone Milling	coarse disc milling	fine stone milling	fine disc Milling	coarse stone Milling	coarse disc milling
A	7.91	4.44	7.61	7.39	7.91	3.47	0.3	0.52	0
B	8.04	4.32	7.58	7.31	8.04	3.72	0.46	0.73	0
C	8.15	4.01	7.55	7.06	8.15	4.14	0.6	1.09	0

The moisture content of flour milled on fine stone milling setting is very low with high milling loss; this can be attributed to the high temperature of milling chamber generated by shear and abrasive force (80°C when tested).Thermal processing is reported to be the most extensively used method in food preservation to destroy microorganisms, and minimize the undesirable changes in lipids, thereby extending shelf-life (Salih *et al*. 2013), (Kadlag *et al*. 1995).

Protein and protein recovery

The protein recovered was found to be 94, 96, and 99% for samples A, B and C respectively. This finding is comparable to the results obtained by (Desikachar 1982) who reported the protein recovery of 10 and 5% decorticated sorghum as 95 and 96.77%. The 1% losses in whole grain protein may be due to excessive milling resulting in protein heat degradation.

Ash content and color

Ash content of samples A, B and C flours were estimated at 1.55, 1.69, and 1.83% respectively the late is not far from (Abdualrahman and Ali 2012) who reported the ash content of Tabat whole grain as 1.78. Referring to Table 2, it is obvious that the ash content of all samples fine milled on stone mill are higher than the original grain ash content. The increase in ash may be due to stone traces made by abrasive and sheer force of excessive milling, (Badi *et al*. 1990); however this finding is in agreement with (Desikachar 1982) who reported that the milling on stone mill can increase the ash by 1.5 - 2%.

Table 2: Ash content

		flour ash content				Semolina ash content		
sample	Grain	fine stone	fine disc	coarse stone	Coarse Disc	fine disc	coarse stone	coarse disc
#		milling	milling	milling	Milling	milling	Milling	milling
A	1.51	1.55	1.51	1.51	1.51	1.5	1.51	1.48
B	1.60	1.69	1.6	1.61	1.6	1.61	1.63	1.58
C	1.71	1.83	1.71	1.73	1.71	1.72	1.71	1.7

Howe ever according to the researchers experience and Pekar test the flour produced is acceptable and with the range of flour color that is available in local Khartoum market. The color test of the flours produced form fine stone milling showed darker color than that produced on coarse stone milling, fine and coarse disc milling. The intensity of milling may affect the color in form of stone fragments traced with flour.

Granularity and size distribution

The granularity test showed that sample A produced the finest flour (97% passed through 280 micron). Sample B was coarser than sample A (95.5 % passed through 280 microns); whereas sample C was found to be the coarsest 84% passed through 280 microns. Fig. 1 and Table 3 show the flour granularity of the fine stone milling. These results indicate that the milling of decorticated or partial decorticated sorghum could produce flour with a very good fineness. These results are far better than (Eggum *et al*. 1982) who reported the flour fineness as 34.4-39.9% over 250 microns for 10 and 5 % decorticated sorghum respectively.

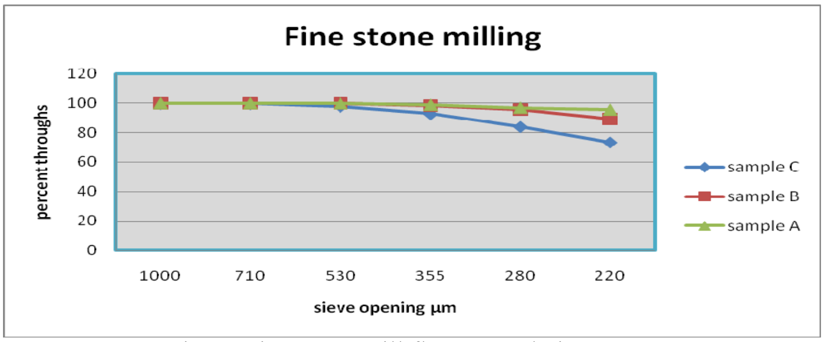

Fig. 1: Fine stone mill flour granulation curve

Table 3: Accumulative overs and throughs of fine stone milling

Sieve opening	Sample A			Sample B			Sample C		
	%over tails	%Accm. Overs	%Accm. Throughs	%over Tails	%Accm Overs	%Accm. throughs	%over tails	%Accm. Overs	%Accm. throughs
1000	0	0	100	000	000	100	0.4	0.4	99.6
710	0	0	100	000	000	100	0.14	0.54	99.46
530	0	0	100	000	000	100	1.76	2.3	97.7
355	1.04	1.04	98.96	1.84	1.84	98.16	5.1	7.4	92.6
280	1.96	3	97	2.64	4.48	95.52	8.6	16	84
220	1.32	4.32	95.65	6.40	10.88	89.12	10.56	26.56	73.44

The overtails stocks of non decorticated sorghum were observed to be mainly bran or branny offals; traces of attached endosperm were also seen overtailing some sieve covers namely 355 microns.

The incidence rates of oral cancer are 3.7% for men and 2.6% for women in the Sudan (GLOBOCAN, 2008). Several lifestyle risk factors for the development of oral cancer are familiar, including tobacco products, alcohol, infections, dietary factors, chemical irritants and frank carcinogens. Prevalence of oral cancer is 3.2% in Sudan and the disease is mainly attributed to N-nitrosamine rich oral snuff consumption (GLOBOCAN, 2008). There are mainly 4 smokeless tobacco products: loose leaf or chewing tobacco, snuff, plug tobacco and twist or roll tobacco (IARC, 1985 Cullen *et al.* 1986). The oral use of snuff in North America and Western Europe is causally associated with an increased risk for cancer of the oral cavity and pharynx, and other pre-neoplastic changes such as leukoplakia (IARC, 1985 Cullen *et al.* 1986). In Sudan, oral snuff, known locally as Toombak, is home-made from finely ground leaves of Nicotianarustica, a tobacco species with a particularly high content of nicotine and minor alkaloids.

Fine Disc Milling

Flour moisture and moisture milling losses

The fine milling on Buhler laboratory disc mill showed less moisture milling losses than that of the commercial stone mill. The milling losses of samples A, B and C were found to be 0.30, 0.46and 0.60 % respectively, Table 1.

Protein and protein recovery

The protein recovery was generally better than that of the fine stone milled flours; samples A, B, and C protein recovery was 95, 97, and 100% respectively.

Ash content and color

It was observed that sample A has the best color, sample B has less dark color and sample C has darker color (in both flour and semolina). Ash content showed no change between grain and stock milled (Table 2). The ash content values obtained are in comparable to the findings of (Abdualrahman and Ali 2012) who reported the ash content of Tabat flour as 1.78%, while the ash content of samples A, and B was closed to values reported by (STPO 2014).

Granularity, size distribution and farinograph test results

Table 4 and Fig. 2 show the granularity of fine flour milled on Buhler laboratory disc mill. Granularity test showed that the fine disc milled flours were coarser than that of the stone milled flours through the three samples. Samples A, B, and C granulation were 70.16, 65.98, and 56.12% through 280 microns respectively. Fine semolina was produced at 33.7, 38.08 and 51.4% from samples A, B, and C respectively. Semolina and flour extracted from samples A, and B was comparable to that extracted by (Viraktamath *et al.* 1971) who recovered 33.5% fine semolina 33.75% flour.

Table 4: Accumulative overs and throughs of fine disc milling

Sieve opening	Sample A			Sample B			Sample C		
	% over tails	% Accm. Overs	% Accm. throughs	% over tails	% Accm. overs	% Accm. throughs	% over tails	% Accm. overs	% Accm. throughs
1000	0	0	100	0	0	100	0.8	0.8	99.2
710	0.04	0.04	99.96	0.18	0.18	99.82	0.46	1.26	98.74
530	0.38	0.42	99.58	0.94	1.12	98.88	2.2	3.46	96.54
355	14.3	14.72	85.28	14.76	15.88	84.12	17.92	21.38	78.62
280	15.1	29.82	70.18	18.14	34.02	65.98	22.5	43.88	56.12
220	4.86	34.68	65.32	5.06	39.08	60.92	8.52	52.4	47.6

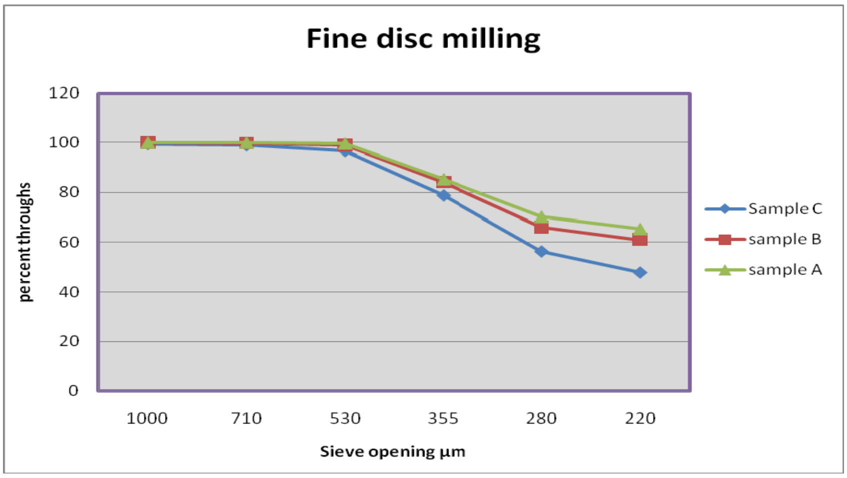

Fig. 2: Fine disc mill flour granulation curve

This semolina was tested as wheat flour improver filler, the sorghum flour and semolina is known to be gritty, so this characteristic will facilitate the mixing and the ingredients will not stick on. Illustrated on Table 5, no significant differences were detected when we compared the results of farigraph test for flour improved with wheat and sorghum as filling material of 0.7%.

Table 5: Farinograph results

Characteristic	Flour improved with	
	wheat semolina carrier	Sorghum semolina carrier
Water absorption (%)	62.1	62.1
Dough development time (min)	4.9	5.0
Stability (min)	7.6	7.6

Coarse Milling Stone

Flour moisture And Protein and protein recovery

The coarse stone milling produced flour with less moisture losses, which were found to be 0.52, 0.73, and 1.09 in samples A, B, and C respectively. While the protein recovery exhibited no change between milled grain and produced stocks; this finding is strengthening that excessive milling may reduce protein recovery.

Ash content and color

Flour produced through 280 microns was 27.77, 20.06 and 18.22% from Samples A, B, and respectively. Coarse semolina showed only slight differences in color between samples A and B; but there was noticeable difference when we compared samples A and C. Ash content of coarse semolina from samples A, B, and C is shown in Table 2. The ash results showed no differences between grain and milled flour except sample B ash is slightly greater.

Granularity and size distribution

Tables 6 and Fig. 3 exhibit the granularity of the coarse stone milling. Two types of semolina were produced; coarse semolina over 710 micron samples A, B and C extracted 61.14, 71.68, and 76.82 respectively. Coarse semolina produced from samples and B has acceptable color, sample C semolina was less dark. The fine semolina extracted through 710 and over 280 microns was found to be 15.61, 12.3 and 6.82% from samples A, B and C respectively.

Table 6: Accumulative overs and throughs of coarse stone milling

Sieve opening	Sample A			Sample B			Sample C		
	% over ails	% Accm. Overs	% Accm. throughs	% over tails	% Accm overs	% Accm. throughs	% over tails	% Accm. Overs	% Accm. throughs
1000	56.62	56.62	43.38	67.6	67.6	32.4	67.6	67.6	32.4
710	4.52	61.14	38.86	4.08	71.68	28.32	4.08	71.68	28.32
530	4.66	65.8	34.2	2.72	74.4	25.6	2.72	74.4	25.6
355	2.5	68.3	31.7	2.82	77.22	22.78	2.82	77.22	22.78
280	2.4	70.7	29.3	1.84	79.06	20.94	1.84	79.06	20.94
220	1	71.7	28.3	0.88	79.94	20.06	0.88	79.94	20.06

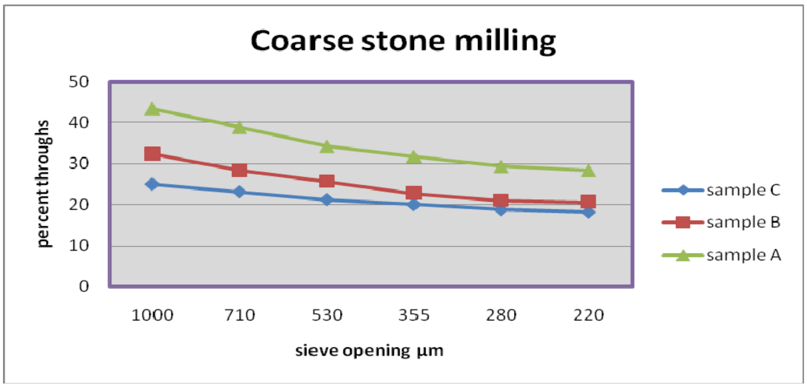

Fig. 3: Coarse stone mill flour granulation curve

Coarse Disc Milling

Flour moisture and protein and protein recovery

Samples of coarse stocks milled on Buhler disc mill did not show any change in moisture losses nor protein content.

Color and ash content

There was no change in ash content between grain and milled flour.

Granularity and size distribution

Table 7 and Fig. 4 demonstrate the granularity of the coarse stocks milled on the disc mill. Two types of semolina were extracted; the coarse semolina was 75.62, 81.22, and 85.96 % from samples A, B, and C respectively. Fine Semolina extracted through 710 and over 280 was 10.49, 8.08, and 6.72 % from samples A, B, and C respectively flour produced was 18.6, 10.3, and 7.25%. Among the three samples the granules size and color sample A quality was the best, sample B has less quality and sample C has the least quality.

Table7: Accumulative overs and throughs of coarse disc milling

	Sample A			Sample B			Sample C		
Sieve opening	%over tails	%Accm. Overs	%Accm. throughs	%over tails	%Accm Overs	%Accm. throughs	%over tails	%Accm. overs	%Accm. throughs
1000	63.02	63.02	36.98	65.7	65.7	34.3	67.5	67.5	32.5
710	12.6	75.62	24.38	14.52	80.22	19.78	17.96	85.46	14.54
530	2	77.62	22.38	3.12	83.34	16.66	4.84	90.3	9.7
355	2.82	80.44	19.56	3.48	86.82	13.18	3.68	93.98	6.02
280	0.9	81.34	18.66	1.48	88.3	11.7	2.06	96.04	3.96
220	0.64	81.98	18.02	1.4	89.7	10.3	1.8	97.84	2.16

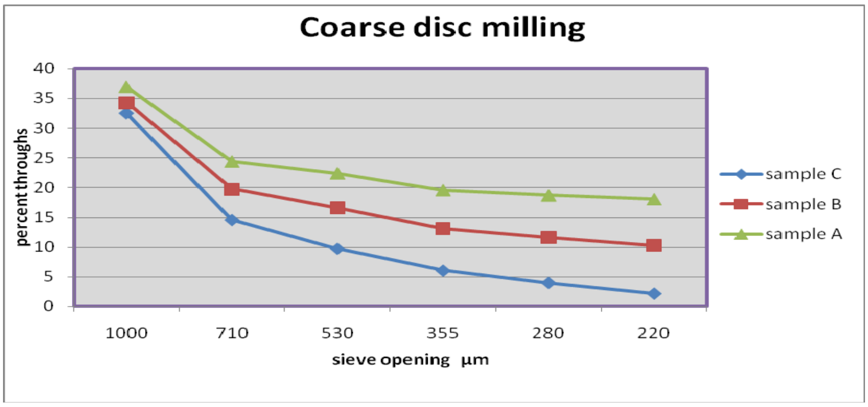

Fig. 4: Coarse disc mill flour granulation curve

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ARABIC SUMMARY

اثر تقنية طحن الذرة على جودة الطحين

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اخذت عينة من الذرة السودانية (طابت) من السوق المحلى بالخرطوم موسم ٢٠٠٩، تمت نظافة واعداد ثلاث عينات. تم قشرها بقشارة تجارية حيث استخلص ١٠، ٥ و٠% من القشرة. اخضعت الثلاث عينات الى عمليات طحن على طاحونة حجارة وطاحونة قرص معملية. تم ضبط الطاحونتين بحيث تنتجا انعم واخشن دقيق ممكن. اخضعت عينات الدقيق الى تحاليل لاختبار بعض صفات الطحين: الرطوبة و الفقد فى الرطوبة والبروتين والفقد فى البروتين، نسبة الرماد واللون والنعومة. عند استبدال سميد القمح بسميد الذرة المنتج واستعماله كمادة مالئة لمحسنات الخبز لم يكن هناك فرق معنوى فى صفات الدقيقين التى ظهرت فى قراءة منحنيات الفارينوقراف. خلصت الدراسة الى انه بالضبط المناسب واستخدام وسيط غربلة مناسب يمكن طحن منتجات متعددة من الذرة طابت المقشور او المقشور جزئياً بدرجة جودة عالية منها : السميد الخشن والسميد الناعم، الدقيق الخشن والدقيق الناعم .