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Physiochemical properties of Sudanese wheat (Debeira) variety obtained from different locations

Khadiga G. Abd Elaleem[*1,2], Ahlam S. Mohamed[3,4], Amani Algali[4], Babiker El Wasila Mohamed[5], Widad Hassan Abdel Halim Hassan[6], Professor Paul Lado Bureng[7]

[1]*Department of Biology and Biotechnology, AL Neelain University, Faculty of Science and Technology, Khartoum, Sudan*

[2]*Department of Biology, University College in Alkhafji, Hafr Elbatin University, Saudi Arabia*

[3]*Department of Biology, University College at Qaria Alolya, Hafr Elbatin University, Saudi Arabia*

[4]*Department of Research Services, Industrial Research and Consultancy Centre, Sudan*

[5]*Department of Food Science and Technology, Faculty of Agriculture, University of Khartoum, Sudan*

[6]*Industrial Research and Consultancy Centre (IRCC), Khartoum, Sudan*

[7]*Faculty of Agriculture, University of Khartoum, Sudan*

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Abstract

This research was carried out to evaluate the quality of Sudanese wheat cultivars namely (Debeira), obtained from three agricultural research station in Sudan, namely; Hudeiba, Medani and Sennar. The physical and chemical characters of wheat grain include; Hectoliter weight, one thousand kernel weight, kernel hardness ,kernel size, moisture content, ash content, crude protein, Alpha-amylase activity, Sedimentation value, wet and dry gluten and Bread specific volume were studied. Hectoliter weight was range from 791.5-851.6, weight of 1000-kernel range from 29.6-35 g, Kernel hardness is ranged from 4.4-9.2 kg/grain and Kernel size range from 3.23-3.64. Values of moisture content were ranged from 8.0-8.5% .Ash content obtained no significant difference (at p ≥0.05) in the ash content of the two locations Hudeiba and Medani, but there was significant difference with those of Sennar location. The protein quantities of Debeira were found to be (13.81±0.4%, 12.70±0.40% and 11.11±0.40%);Wet and dry gluten were 25.2 ± 0.52, 11.3 ± 0.24%; 23.7±0.52% and 10.5±0.24%; and 21.7±0.52% and 9.8±0.24%; Sedimentation values as follow (16.0±0.9 ml, 11.4±0.90 ml and 10.2±0.9 ml), in the three locations Hudeiba, Medani and Sennar respectively. The Alpha-amylase activity showed a decrease of enzyme Alpha- amylase activity in the three locations Hudeiba (393±7.5 second), Medani (410±7.5 second) and Sennar (442±7.5 second). The outcomes obviously indicate that the investigated Sudanese wheat Debeira cultivar that grown in Hudeiba could efficiently be used for bread making.

* **Corresponding Author:** Khadiga G. Abd Elaleem ✉ khadigaalaim@hotmail.com

Introduction

Wheat (*Triticum* spp.) is a cereal grain, originally from the Levant region of the Near East, but now cultivated worldwide (Belderok *et al.,* 2000). Wheat is grown on more land area than any other commercial crop and is the most important staple food for humans. World trade in wheat is greater than for all other crops combined (Curtis *et al.*, 2002). Wheat grain is a staple food used to make flour for leavened, flat and steamed breads, biscuits, cookies, cakes, breakfast cereal, pasta, noodles, couscous (Cauvain *et al.*, 2003). The quality of wheat flours can be defined for several parameters including Hectoliter weight, one thousand kernel weight, kernel hardness , kernel size, moisture content, ash content, crude protein, falling number (Alpha-amylase activity), Sedimentation value, wet and dry gluten and Bread specific volume, none of which serves as adequate by itself. Bread making potential is derived largely from the quantity and quality of a flour protein (Hruskova and Famera 2003). Gluten proteins substantially control the quality of wheat and allow the dough to be processed into a lot of different end-use products including breads.

The structures of gluten proteins and properties make them interesting for studies relating to functional properties (Shewry and Tatham, 2000).Although total protein content is the primary factor in characterizing wheat flour, it is not enough. Therefore, it is necessary to determine the gluten properties as well as protein quality. Moreover, wheat flour's strength is based on the gluten quality and content (Jirsa and Hruskova, 2005). The problem of study is that Sudan climate is differ than temperate regions of wheat production, therefore, the imported wheat for Sudan domestication required breeding programmer to inherit the recommended characters, nevertheless, quality is a crucial factor to be determine. The objective of this study is to evaluate the quality of Sudanese wheat cultivar (Debiera) by studying different characteristics of wheat grain such as; Hectoliter weight, One thousand kernel weight, Kernel hardness and Kernel size; also ash content, protein content, falling number (alpha-amylase activity), Sedimentation value, wet and dry gluten and Bread specific volume were studied.

Materials and methods

Source of plant materials

The local wheat variety namly Debeira, were obtained from the Agricultural Research corporation station at (Hudeba, Medani and Sennar) Sudan.

Sample preparation

Cleaning of wheat grains was done by aspiration sieving and manual separation of impurities by hand. For uniform seeds, 2.8 mm sieve was used for removing small grains. Wheat grains (1 kg sample) were conditioned to 13% moisture for 24 hours, water to be added was calculated according to the general equation below : -

Water to be added (ml) to raise moisture to 13% =

$$= \left[\frac{100-\text{grain moisture}}{100-\text{moisture required (13\%)}}\right]\text{-1 x 1000}$$

The conditioned and tempered grains were milled in quadrumat junior mill using nylon sieve 160 mesh.

Physical analysis

The physical characters such as, 1000 kernel weight, hectoliter weight, grain hardness (kg/grain) and grain size was determined according to AACC, (AACC, 2000).

Hectoliter weight (gm/hectoliter)

A hectoliter weight measuring device was used. The funnel was filled with grains while its gate was opened and grains flow down into the cylinder until overflowing, and then leveled by the leveler attached to the cylinder top. The weigh was measured and recorded as gm/hectoliter.

Thousand kernel weight (gm)

Thousand kernel weights were measured using a representative sample by quartering method. The original grain sample was divided by a ruler into four quarters , two of them were removed and replaced in a sample bag , the remaining quarters were again shaped into a circle and quartered, this process was repeated until the reasonable amount of sample was obtained from which 1000-kernel were weighed in gm.

Grain hardness (kg/grain)

Kernel hardness tester model no 174886, was used to calculate grain hardness. Fifty sound kernels were randomly taken and tested for hardness. Each kernel was placed on the tester dish under needle and the tester handle was screwed until breakage of the kernel. The pressure needed to break each kernel was recorded and the mean number of kilograms used to break the kernel of each treatment was calculated.

Grain size

The physical characteristics such as length, width and thickness were determined in 50 randomly selected grains using a Vernier caliper. Grain size was calculated as follows:

Size (mm^3) = (length x width x thickness) ⅓

Chemical analysis

Moisture, ash content, crude protein, falling number, sedimentation value, Determination of gluten and the specific bread volume were determined according to the approved AOAC standard methods (AOAC, 1995).

Statistical analysis

Replicates of each sample were analyzed using statistical analysis system (using SPSS program).

The analysis of variance was performed to examine the significant effect in all parameters measured Least significant difference (LSD) test was used to separate the means (Peterson, 1985).

Results and discussions

The physical characteristics of wheat grain variety Debeira from three different locations (Hudeiba, Medani and Sennar) results are shown in Table 1.

Hectoliter weight (Test weight)

Hectoliter weight was important factor in wheat grading systems.

It was the bulk density measurement that indicates the weight of grains per unit volume (g/liter).

Table 1. Physical characteristics of wheat grain (Debeira).

Location	Hectoliter Wt (g/L)	1000-kernel wt. (gm)	Hardness (kg/grain)	Size (mm^3)
Hudeiba	791.5	29.6	9.2	3.23
Medani	800.0	34.2	6.1	3.44
Sennar	815.6	35.3	4.4	3.64
Mean	802.63	33.03	6.57	3.44
CV%	1.140	1.55	3.05	0.76
SE±	5.30	0.30	0.12	0.02
Lsd	18.35	1.03	0.40	0.06

Mean values with the same letter within the same column are not significantly different at p≥0.05**.**

Its importance, it was at least a rough index of the flour quality. In table 1, the values of hectoliter weigh for Debeira variety range from (791.5-851.6) (mean 802.63±1.14 g/l) (grams per liter), the highest weight was shown by Sennar locations grains (815.6 grams per liter) so it is (81.56 kilogram per hectoliter); while the lowest value was shown by the grains of Hudeiba location (791.5grams per liter) so it is (79.15kilogram per hectoliter). The result, showed significant differences (p≥0.05) among the three locations in their hectoliter weight.

The result is in agree with(Atwell, 2001), who reported that test weights may range from about 57.9 kg/hl (kilograms per hectoliter) for poor wheat to about 82.4 kg/hl (kilograms per hectoliter) for soundness wheat. The result proves that Debeira variety is soundness and at high quality.

One Thousand Kernel Weight

The values of one-thousand kernel weigh from the three locations were significantly different (at p≥0.05,

Lsd 1.03) as shown in Table 1, it ranged from (29.6-35.3) g (mean 33.03 ±0.30 g).

The highest kernel weigh value was found in wheat from Sennar (35.3) whereas; the lowest value was shown by grains from Hudeba location (29.6).

The mean value of one thousand kernel weight of wheat was reported by (Zeleny, 1971) as 35 gram. Medani location produces an intermediate 1000-kernel weigh (34.2) as it lies between the two extreme environments of long and short-cold seasons for Hudeiba and Sennar respectively.

The result in agree with (Abubaker *et al*., 2013) reported that One Thousand Kernel Weight of three Sudanese wheat cultivars grown in Khartoum state ranged of 31.7 to 32.9 g. Similarly (Ahmed, 1995) and Mutwali (2011) obtained that the thousand kernels weight of twenty Sudanese cultivars ranged between 28.0 – 44.0 and 28.7 - 48.5g, respectively. Moreover, Zeleny (1971) found that the thousand kernels weight for hard red spring and hard red winter heats ranged from 20 to 32g, whereas soft white and durum wheat ranged from30 to 40g. However, (Mohamed, 2000) reported that the thousand kernels weight of four Sudanese wheat cultivars between 32 and 38g.Weigh of One Thousand Kernel was a parameter for evaluating the plumpness and maturity of food grains. It was an important parameter in the grain standards in the international trade. Generally, larger grains give higher yield of flour than small ones.

The 1000-kernel weight also gives an indication of the size and weight of the wheat grain, which affects the percentage of the different components, such as ash, fiber and starch. Small or shriveled kernel usually has more crude fiber and ash with less flour yield (Zeleny, 1971).

Kernel hardness

Kernel hardness is one of the most important factors in determining the quality of wheat. As shown in Table 1, the values of kernel hardness were significantly different in the three locations.

It ranges from (4.4-9.2) kg/grain (mean 6.57±0.12 kg/grain) at p≥0.05 Lsd 0.40. The highest value of hardness was shown by grains from Hudeiba location (9.2), whereas the least value was shown by Sennar location grains (4.4).

The result obtained that the grain hardness is effected by growth location and environmental factors, thus is agree with (Anjum and Walker, 2000) who used Kansas State University hardness tester, based on the kernel shearing principle, along with pearling value and NIR hardness to measure grain hardness in Pakistani wheat varieties and found all hardness methods were affected by cultivar, growth location and years.

Kernel size

The values of kernel size were significantly different in the three locations .It range from 3.23-3.64 mm (mean 3.44±0.02mm^3) at p≥0.06.

The highest value was shown by Sennar location, which the kernels size is (3.64mm^3), at the same time had the lowest hardness (4.4kg/grain**)**, while the lowest value shown by Hudeiba location, which is (3.23 mm^3), which had higher hardness (9.2kg/grain).

The result is agree with (*Dariusz and Janusz, 2004)*,reported that the large kernels (fraction 3.1–3.5 mm) had the lowest PSI hardness index and ash content (Pomeranz *et al.*, 1985) found a similar dependency between kernel size and kernel hardness.

Effect of location on chemical analysis of wheat grain

Results of the effect of location on wheat quality of variety Debrira (on dry weight basis) were shown in Table 2.

Moisture content

The data of the chemical characteristics are presented in Table 2. Moisture content of wheat flours was ranged from (8.5-8.0) %, mean (8.3±0.07) %. Analysis of variance showed significant differences [p≥0.05%] among the different location. The values of moisture content were significantly different in the three locations.

Sennar and Medani wheat sample showed the highest value of moisture percentage, while the lowest values of moisture content were shown by wheat sample of Hudeiba (8.0) %, compare with Sennar (8.5) and Medani (8.4).

It could be observed that from these results the values of moisture content of the three locations were relatively low.

Table 2. Effect of location on wheat quality of Debeira variety.

location	Moisture (%)	Ash (%)	Protein (%)	Falling Number (sec)	Sedimentation (ml)	Wet gluten (%)	Drygluten (%)	Bread specific volume (ml/g)
Hudeiba	8.0	2.01	13.81	393	13.0	25.2	11.3a	4.46
Medani	8.4	1.97	12.70	410	11.4	23.7	10.5	3.79
Sennar	8.5	1.52	11.11	442	10.2	21.7	09.8	3.69
Mean	8.3	1.83	12.54	415	12.5	23.5	10.5	3.98
CV	1.45	5.09	1.68	1.93	3.54	1.62	3.77	1.74
SE±	0.07	0.08	0.40	7.50	0.90	0.52	0.24	0.12
Lsd	0.24	0.19	0.42	0.89	0.88	0.76	0.80	0.14

Mean values with the same letter within the same column are not significantly different at p≥0.05.

The results obtained here were in agreement with values obtained by (Ahmed, 1995; Mohamed, 2000; and Elagib, 2002), they found that the moisture values of Sudanese wheat cultivars ranged from 6.33 to 8.60 %. Lower values obtained may be due to longer and drier winter season in which wheat cultivars were grown. Variations in moisture content were due to different localities environment and relative humidity.

Ash content

The ash content was found to be ranged from (2.01-1.52). The grains from Hudeiba and Medani locations showed high values of ash content (2.01 and1.97) respectively, while Sennar location showed low value (1.52). There was significant difference in ash content of wheat grains from Hudeiba and Sennar; Medaniand Sennar locations at p≥0.05 Lsd 0.19, while there was no significant difference (P >0.05) were found between Hudeiba and Medani locations. These results were higher than those reported by (Mutwali, 2011) who found that the ash content of 20 Sudanese wheat cultivars was ranged between (0.47 to 0.85)% and (Abubaker *et al*., 2013) who found that the ash content of three Sudanese wheat cultivars was ranged between (0.31to 0.39)%. This could be attributed to differences in wheat cultivars, soil conditions, water and temperature.

Protein content

Both protein quantity and quality were considered to be primary factors in measuring the potential of flour in relation to its end use. The quantitative expression of crude protein was related to total organic nitrogen in flour whereas, quality evaluations relate specifically to physicochemical characteristic of gluten forming component (Pratt, 1971). The crude protein of variety Debeira in the three locations showed significant difference at p≥0.05 Lsd 0.42 ranged from (11.11-13.81) %, (mean12.54±0.40%). Lowest value (11.11%) of protein was observed in Sennar location grains and the highest value (13.81%) in, Hudeiba location grains. The results of the present study are in consistent with the results reported by (Abubaker *et al*., 2013)who reported variation in protein content among Sudanese wheat varieties from 9.5to 12.9 % and (Mutwali, 2011) reported protein content of white flours of twenty different Sudanese cultivars grown in three different locations ranged between9.59% and 14.06%. So, with regards to protein content Sudanese wheat Debiera cultivar grown at Hudeiba, Medani Sennar could possibly be used for bread making. The protein content of wheat was highly influenced by the environmental conditions.

Falling number (alpha-amylase activity)

Alpha-amylase activity was one of the most important factors affecting bread making, alpha-amylase activity estimated by falling number method. The high values of falling number showed significant difference in the three location, it ranged from (393-442) seconds, (mean 415±7.5 seconds) at p≥0.0 Lsd0.89. The highest value of falling number (low alpha-amylase activity) was shown by grains of Sennar location (442) second, while the lowest value (high alpha-amylase activity) was shown by grains from Hudeiba location (393) seconds. Similarly, higher falling numbers in the range of 396 and 486 sec were reported by Ahmed (1995) some Sudanese wheat cultivars, by contrast (Abubaker *et al* ., 2013) showed that the high falling number values of three Sudanese wheat cultivars ranged between 883 and 1032 seconds. The falling numbers above 400 second indicated that the flour is deficient in alpha- amylase and that the flour should be supplemented with a form of amylase to achieve the desirable level of enzyme activity (Cauvain and Young, 2001).Low tendency towards high alpha-amylase activity in wheat grain in wet climates and that the activity of the same enzyme was commonly low in the dry climate. This could offer an explanation for the low alpha-amylase activity observed in this study. If the falling number is too high, enzymes can be added to the flour in various ways to compensate. If the falling number is too low, enzymes cannot be removed from the flour or wheat, which results in a serious problem that makes the flour unusable.

Sedimentation value

The sedimentation values of the three locations ranged from (10.2-16.0) ml (mean12.5±0.90ml), the highest value was given by wheat from Hudeiba (16.0 ml), while the lowest sedimentation value given by those from Sennar (10.2 ml). This results is dis agree with (Abubaker *et al* ., 2013**)** reported a range of 15.0 to 30.0 ml for the sedimentation value of three Sudanese wheat cultivars grown at Khartoum state(Mutwali, 2011) reported a range of 19.0 to 40.3 ml for the sedimentation value of twenty Sudanese wheat cultivars grown at three different locations. While, (Mohamed, 2000) showed that, the sedimentation value of Sudanese wheat five cultivars ranged between 21 and 24 ml. The variation in result might be due to variation in cultivar and environmental condition. Sedimentation value, however, should be more than 20% for optimum bread making quality (SDS 036/2007). None of the three location wheat grain gave similar values of sedimentation (20 ml).

Wet and Dry gluten

Gluten percentage of the three locations showed significant difference. Wet gluten ranged from 21.7-25.2% (mean23.5±0.52%). The maximum value (25.2%) was found for Hudeiba whereas the minimum value (21.7%) was observed for Sennar location grain. These result is disagree with, (Mutwali, 2011) reported that the wet gluten value of 20 Sudanese cultivars is ranged between 28.63% and 46.94%, this may due to varied in cultivars. The results obtained in this study indicated that Debeira from Hudeiba location has the best gluten quality than Debeira from other two locations. The dry gluten values were found to be ranged between **(**9.8-11.3) % (mean 10.5±0.24%).

The highest values were given by Hudeiba wheat grains while the lowest values were given by those of Sennar location. Gluten was considered to be an important factor in wheat flour quality which gives wheat flour its baking character, thus the gluten was in reality the skeleton or frame work of wheat flour drought and was responsible for gas retention, this property gives volume , texture and appearance of the bread (Meredith, 1964).

Bread specific volume

The values of bread specific volume ranged from 3.69-4.46 ml/g (mean 3.98±0.12ml/g) at p≥0.0 and Lsd 0.14. There was no significant difference between values of the two locations Medani and Sennar with the lowest value of bread volume while Hudeiba location wheat produces the highest value.

This results are well agreed with those by (Abubaker *et al.*, 2013) who reported a range of 3.06 cm^3 to 3.40cm^3/g from Sudanese wheat cultivars that grown in Khartoum state, (Mutwali, 2011) who reported a range of 2.4 to 3.54 cm /g that the bread specific volume of eight Sudanese wheat cultivars grown at three different location. Alpha-amylase provides fermentable sugar for yeast fermentation to produce Bread with softer crumb and greater volume (due to carbon dioxide production) and improves grain and texture .This was clearly observed in this study, that with increasing alpha-amylase activity (decreasing falling number) the bread volume increases and also the softness of crumb increases. Finney (1943) reported that the bread volume was and indicator of baking quality, varying linearly with protein content. However, (Macritchie, 1997) found that the differences in performance were due to gluten content.

This could offer an explanation for the results of this study with the result obtained from two locations Hudeiba and Medani. Wheat with high protein and gluten percentages gave bread with high specific volume whereas; the wheat of Sennar location with low protein and gluten percentages gave bread with low specific volume. Earlier report (Meredith,1964 and Macritchie ,1997) showed that the bread volume increase with the increase in protein, gluten, hardness values and alpha-amylase activity , these agree with the results obtained in this study.

Conclusion

Generally, the above outcomes obviously indicate that the investigated Sudanese wheat Debeiracultivar that grown in Hudeiba have lower moister, higher values of Ash (%), Protein (%), Sedimentation (ml), Wet gluten (%), Dry gluten (%)and bread specific volume(ml/g); and lower Falling Number (sec)thus, could efficiently be used for bread making.

References

AACC. 2000. Approved Methods of the American Association of Cereal Chemists. Method.38-12,10th edition. American Association of Cereal Chemists, Paul, MN, USA.

Abubaker Bashir Makawi, Mohamed Ishag Mahmood, Hayat Abdel Rahman Hassan, Isam A, Mohamed Ahmed. 2013. Grains Quality Characteristics of Local Wheat (*Triticum aestivum*) Cultivars Grown at Khartoum State, Sudan International Journal of Life Sciences **7(1),** 1 2 - 1 6.

Ahmed SE. 1995. Proximate Composition and Flour Quality of Wheat Cultivars Grown In Sudan. M.Sc. Thesis, University of Khartoum.

Anjum FM, Walker CE. 2000. Grain, flour and bread making properties of eight Pakistani hard white spring wheat cultivars grown at three different locations for 2 years, International Journal of Food Science and Technology **35,** 407-16.

AOAC. 1995. Official methods of analysis, 16th ed. Association of Official analytical chemistry, Washington, DC.

Atwell WA. 2001. Wheat Flour. Eagan Press Handbook Series. St. Paul, Minnesota, USA.

Belderok Bob, Hans M, Dingena A, Donner. 2000. Bread-Making Quality of Wheat, Springer; p.3. ISBN, 0-7923-6383-3.

Cauvain S, Young L. 2001. Flour in S. Cauvain and L. Young (Eds.), Baking problems solved". Cambridge: Wood Head Publishing Limited, p 19- 37.

Cauvain Stanley P, Cauvain P. 2003. Bread Making. CRC Press; p. 540. ISBN1-85573-553-9.

Curtis, Rajaraman, Mac Pherson. 2002. Bread Wheat. Food and Agriculture Organization of the United Nations.

Dariusz Dziki, Janusz Laskowski. 2004. Influence of Kernel Size on Grinding Process of Wheat at Respective Grinding STAGES.POLISH. Journal of Food and Nutrition Sciences **(13/54)1,** p. 29–33.

Elagib EAA. 2002. A study of the proteins and baking quality of three Sudanese wheat cultivars. Ph.D. Thesis, Faculty of Agriculture, University of Khartoum.

Finney KF. 1943. Fractionating Reconstituting Techniques as Tools in Wheat Flour Research. Journal of. Cereal Chemistry, **20,** 381. Cited by Mac Ritchie, F., (1978). Differences in Baking Quality between Wheat Flours. Journal of Food Technology; **13,** 187.

Hruskova M, Famera O. 2003. Prediction of wheat and flour Zeleny sedimentation value using NIR technique. Czech Journal of Food Sciences **21,** 91-96.

Jirsa O, Hruskova M. 2005. Characteristics of fermented dough predicted by using the NIR technique. Czech Journal of Food Sciences **23,** 184-189.

Macritchie F, Lafiandra D. 1997. Structure-Functionality Relationships of Wheat Proteins. In: Food Proteins and their Applications (Damodaran, and S. Paraf, A. Eds), M. Dekken Inc. New York.

Meredith P. 1964. Theory of Gluten Structure. Cereal Science Today **9,** 33-37.

Mohamed EA. 2000. Evaluation of four local wheat cultivars with special emphasis on protein fractions, M.Sc. Thesis, University of Khartoum, Sudan.

Mutwali NIAK. 2011. Quality of wheat cultivars grown in different locations of Sudan for bread making. Ph.D. Thesis. Department of Food Science and Technology, Faculty of Agriculture, University of Khartoum.

Peterson RG. 1985. Design and analysis of experiments, March Dekker Inc., New York, p 429. Hardness of winter wheat grown under widely different climatic conditions, Cereal Chemistry **62,** 463–467.

Pratt DB. 1971. Criteriaof flour quality. In Y. Pomeranz (Ed.).Wheat: Chemistry and Technology (pp. 201-226). St. Paul:AACC.

SDS. 2007. Sudanese Standard and Specification; Wheat flour Standard. 037/2007.

Shewry PR, Tatham AS. 2000. Wheat gluten. Paper presented at: 7th International Workshop Gluten (University of Bristol).

Zeleny L. 1971. In: wheat chemistry and technology". Pomeranz, Y., second (Edt). American. Association of Cereal Chemistry. St. Paul, Minnisota. p 19-40.