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Statistical analysis of the basic chemical composition of whole grain flour of different cereal grains

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Abstract. Samples of whole grain flour of five cereals (wheat, rye, barley, oats and buckwheat) were analysed for ash, starch, fat, cellulose and protein content. Coefficient of variation shows that within the same sample of whole grain flour variation of starch, protein, fat and ash content is relatively small, rarely exceeding 3%. The variability of the cellulose content is relatively high. The significance of the difference between chemical compositions of two independent samples of the same whole grain flour has been tested by Student's t-test. With the exception of protein content, the difference between two samples of buckwheat whole grain flour

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was significant. With the exception of wheat whole grain flour, for other cereals, the difference in ash content between two samples was significant. In all the other cases, there was no significant difference between two independent samples of the same whole grain flour. The significance of the difference in chemical compositions between the whole grain flour from different cereals has been tested by analysis of variance. Barley whole grain flour shows significant difference in ash content, while wheat whole grain flour significantly differs in starch content compared to other flour samples. All investigated samples significantly differ in fat content. Oat (higher content) and rye (lower content) whole grain flour significantly differ to other samples considering the protein content.

1 Introduction

Cereals are the fruits of cultivated grasses, members of the Gramineae family (*Kent*, 1975). Although a great number of cereal grains exist, eight are considered to be a principal cereal crops (cereals of commerce): wheat, corn, barley, rye, oat, rice, sorghum and millet (*Hoseney* & *Faubion*, 1992). Buckwheat is not a true cereal and belongs to the Polygonaceae family (*Marshall* & *Pomeranz*, 1982), but it is typically associated with the grain family due to similar composition. Although different types of grain differ markedly in their proximate physical composition, all share the same basic anatomical structures: an outer bran layer, a germ fraction and a starchy endosperm (*Hoseny*, 1998). Each of the main parts of the grain has different structural characteristics and chemical composition, and it is further subdivided into various layers (*Kent*, 1975). Depending on the type of grain, bran constitutes approximately 3-30% of its dry weight. The outer bran layer includes the seed coat (pericarp and testa), while the inner layers are composed of aleurone cells, positioned next to the starchy endosperm. Some cereal grains (oat, rice and barley) also possess outer hulls, which are tightly bound to the bran layer. Both the amount and composition of bran are highly variable across the different types of grain (*Hoseny*, 1998). The bran layer is associated with a wealth of macro- and micronutrients, including fibre, protein, B vitamins, minerals and flavonoids. The germ makes up 4-17% of the dry weight of a whole grain. The germ is a rich source of proteins, lipids, B vitamins and vitamin E. The starchy endosperm makes up approximately 65-75% of the dry weight of a cereal grain, and it is composed of starch, non-starch polysaccharides and small amounts of protein and lipids (*Marquart et al.*, 2002).

Traditional flour milling process produces refined flour. During this process, the bran and germ layers of grain are removed in order to stabilize the raw material and to increase the keeping quality. Unfortunately, the type of milling used for refined flour leads to the loss of certain nutrients (Nestle, 2006). If the bran, germ and endosperm components are retained during the milling process, the resulting flour is classified as whole grain (*Franz & Sampson*, 2006). Whole grains contain all the essential parts and the same balance of nutrients that are found in the original grain seed. Compared to refined flour, whole grains are nutritionally superior; they are richer in dietary fibre, protein, antioxidants, dietary minerals and vitamins. Diet rich in whole grain foods has been associated with decreased risk of cardiovascular disease, diabetes, obesity and certain cancers (*Jacobs et al.*, 1998; *McKeown et al.*, 2002; www.healthgrain.com). These are the reasons why the consumption of whole grain flour attracts more and more attention.

Although cereal grains have many structural similarities, they do differ in the relative proportion of their principal components and subsequently in the chemical composition of whole grain flours. The aim of this study was to test the significance of the difference in basic chemical compositions between the whole grain flour from different cereals by analysis of variance (ANOVA).

2 Materials and method

Materials

Commercially available whole grain flours of five different cereals, namely wheat, rye, barley, oat and buckwheat were used for the present study. Two independent samples (2×1 kg) of each of the whole grain flour type were analysed.

Methods

For each sample chemical characteristics, namely moisture, starch, cellulose, fat, protein and ash, analyses were carried out as per standard methods. Moisture content has been determined based on the weight loss suffered by the sample when dried at a temperature of 130 to 133 °C (*ICC standard method No.110/1*). Starch content has been determined according to Ewers polarimetric method (*ISO 10520*), using the Elmer-Perkin polarimeter. Crude cellulose content has been determined according to Kirschner-Ganakova's procedure (*Ćirić et al.*, 1975). Crude lipids were extracted from the samples in a Soxhlet extractor with ether. The crude fat content was determined gravimetrically

after oven-drying. The crude protein content was calculated by multiplying the corresponding total nitrogen content, which was determined according to the Kjeldahl method (*ICC standard method No.105/2*), by a factor of 6.25. To determine the ash content, the samples were placed in a muffle furnace at 900 °C for 2 hours, and weighed before and after (*ICC standard method No.104/1*). The results are expressed as percentage by weight of sample, and presented on a dry matter basis. Each analysis was carried out in triplicate and mean values ± standard deviation reported.

Statistical analysis

The data were analysed by the following statistical procedures: coefficient of variation, t-test and ANOVA (performed by STATISTICA 12). The means were compared using the Tukey test at the 95% significance level.

3 Results and discussion

Representative values for the proximate composition of the investigated whole grain flour samples are shown in *Table 1.* However, for any cereal, a wide range of values for each chemical constituent can be encountered when a series of samples is analysed. This is the reason why the figures given in *Table 1* are limited only to reveal the major differences between the investigated whole grain flours.

The highest protein and fat (lipid) contents were registered in whole grain oat flour. Compared with other cereals, oats are known to contain high amount of protein and especially lipids. The protein content (16.91-17.46%) was within the range (15-20%) as reported by Robbins et al. (1971) and *McMullen* (1991). The lipid content (6.41-6.49%) also was within the range (5-9%) reported previously (*Youngs*, 1986; *Saastamoinen et al.*, 1989). The highest ash and cellulose contents were registered in whole grain barley flour. The mineral and cellulose (fibre) contents are higher in barley compared to other cereals as a consequence of the presence of hull. The hull (10% of the grain dry weight) is undesirable for human consumption and it needs to be removed before the covered grain can be used as a raw material for flour production. After removing the hull, the differences in mineral and cellulose contents are much reduced. However, since the parts of the outer layers of the kernel are removed, some may not regard this flour as a whole grain (*Andersson* & *Aman*, 2008). As expected, the highest starch content was registered in whole grain wheat flour.

Table 1: Ash, starch, cellulose, fat and protein content in the samples of whole grain flour

Sample	Ash $(\%)_{dm}$	CV (%)	Starch $(\%)_{dm}$	CV (%)	Cellulose $(\%)_{dm}$	CV (%)	Fat $(\%)_{dm}$	CV (%)	Protein $(\%)_{dm}$	CV (%)
Barley 1	2.52 ± 0.007	0.27	60.98 ± 1.404	2.30	3.25 ± 0.382	11.74	1.87 ± 0.038	2.02	15.25 ± 0.328	2.15
Barley 2	2.42 ± 0.017	0.68	59.50 ± 0.241	0.41	2.85 ± 0.126	4.44	1.82 ± 0.044	2.42	14.53 ± 0.067	0.46
Oat 1	1.69 ± 0.017	0.56	62.69 ± 1.436	2.29	1.33 ± 0.196	14.69	6.41 ± 0.306	4.77	17.46 ± 0.769	4.40
Oat 2	2.01 ± 0.009	0.97	63.57 ± 0.931	1.46	1.40 ± 0.078	5.56	6.49 ± 0.162	2.50	16.91 ± 0.010	0.06
Wheat 1	1.57 ± 0.004	0.26	69.31 ± 2.100	3.03	2.24 ± 0.096	4.28	1.48 ± 0.032	2.14	14.78 ± 0.092	0.62
Wheat	21.57 ± 0.027	1.72	69.82 ± 2.010	2.87	2.01 ± 0.437	21.67	1.53 ± 0.012	0.77	14.98 ± 0.448	3.00
Buckwheat 1	2.00 ± 0.024	1.21	60.35 ± 0.457	0.76	2.87 ± 0.027	0.93	2.51 ± 0.060	2.40	15.70 ± 0.329	2.10
Buckwheat 2	1.60 ± 0.146	9.14	62.97 ± 0.893	1.42	2.59 ± 0.121	4.66	2.38 ± 0.053	2.25	15.15 ± 0.194	1.28
Rye 1	1.52 ± 0.007	0.46	62.23 ± 0.849	1.36	1.71 ± 0.097	5.66	1.17 ± 0.124	10.60	13.74 ± 0.355	2.58
Rye 2	1.66 ± 0.036	2.19	62.44 ± 0.627	1.00	1.85 ± 0.045	2.42	1.23 ± 0.087	7.03	13.98 ± 0.146	1.04

Values are mean ± standard deviation of three independent determinations; dm – dry matter basis CV – coefficient of variation

Generally speaking, the values presented in *Table 1* are within the range of values previously reported for the chemical composition of wheat (*Kent*, 1975), buckwheat (*Marshall & Pomeranz*, 1982; *Steadman et al.*, 2001), rye (*Vinkx & Delcour*, 1996), oat (*Kaukovirta-Norja* & Lehtinen, 2008) and barley (*Andersson & Aman*, 2008).

The statistical analysis was performed in three steps. In the first step, the coefficient of variation showed that within the same sample of each of the investigated whole grain flour the variation of starch, protein, fat and ash content is relatively small, rarely exceeding 3%, and in lot of the cases even below 1% (*Table 1*). Ash content in the Buckwheat 2 sample and the fat content in both of the rye samples can be considered an exception from this general conclusion. On the contrary, the variability of the cellulose content was relatively high (up to 21.67%).

In the second step, the significance of the difference between the chemical compositions of two independent samples of the same whole grain flour was tested using the Student's t-test. With the exception of protein content, the difference was significant between the two samples of buckwheat whole grain flour. With the exception of wheat whole grain flour, for other cereals, the difference in ash content between the two samples was significant. In all the other cases, there was no significant difference between two independent samples of the same whole grain flour. In the third step, the significance of the difference between the chemical compositions of the whole grain flour from different cereal grains was tested by the ANOVA (*Table 2*).

Table 2: The significance of the difference between the chemical composition of whole grain flour samples tested by ANOVA

Sample	Cellulose $(\%)_{dm}$	Ash $(\%)_{dm}$	Protein $(\%)_{dm}$	Starch $(\%)_{dm}$	Fat $(\%)_{dm}$
Barley	3.03 a	2.47 a	14.89 b	60.24 c	1.85 a
Oat	1.37 c	1.85 b	17.19 a	63.13 b	6.45 b
Buckwheat	2.73 a	1.80 bc	15.43 b	61.66 bc	2.44 c
Rye	1.78 b	1.59 c	13.87 c	62.34 bc	1.20 d
Wheat	2.13 b	1.57 c	14.88 b	69.57 a	1.50 e

Values are the means of six independent determinations; dm – dry matter basis. Means with the same letter do not differ significantly.

ANOVA showed that, in terms of cellulose content, there was no statistically significant difference between barley and buckwheat flour or between wheat and rye flour, while the oat flour is significantly different from all other types of whole grain flours. By ash content, barley flour is allocated in a separate group. A relative closeness exists between oat and buckwheat flour, while at the same time the buckwheat flour is in the same group with wheat and rye flour. Considering the protein content, oat flour (higher content) and rye flour (lower content) significantly differ to other flour samples. Considering the starch content, the investigated flours were classed into three groups. Wheat flour is in a separate group. Barley and oat flour are different from each other; however, they are not significantly different from buckwheat and rye flour. All investigated whole grain flour samples significantly differ in fat content.

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References

[1] A. A. H. Andersson, & P. Aman, Functional barley products. In: Technology of functional cereal products. B. R. Hamaker (ed.), *Woodhead Publishing Limited, CRC Press*, Cambridge (2008) 261–280.

[2] D. Ćirić, B. Vujičić, Ž. Bardić, Handbook for quality control of raw materials and fruit and vegetable products. *Faculty of Technology*, Novi Sad (1975) 227.

[3] M. Franz, & L. Sampson, Challenges in developing a whole grain database: Definitions, methods and quantification. *J. Food Compos. Anal.*, 19. (2006) S38–S44.

[4] R. C. Hoseney, & J. M. Faubion, Physical properties of cereal grains. In: Storage of cereal grains and their products. D. B. Sauer (ed.), *American Association of Cereal Chemists, Inc.*, St. Paul, Minnesota (1992) 1–38.

[5] C. A. Hoseny, Principles of cereal technology. *American Association of Cereal Chemists*, Inc., St. Paul, Minnesota (1998).

[6] ICC Standard Method No.110/1, Determination of moisture content of cereals and cereal products (Practical Method). *International Association for Cereal Science and Technology*, Vienna (1976).

[7] ICC Standard Method No.104/1, Determination of ash in cereals and cereal products. *International Association for Cereal Science and Technology*, Vienna (1990).

[8] ICC Standard Method No. 105/2, Determination of crude protein in cereals and cereal products for food and for feed. *International Association for Cereal Science and Technology*, Vienna (1994).

[9] ISO 10520, Native starch – Determination of starch content – Ewers polarimetric method (1997).

[10] D. R. Jacobs Jr., L. Marquart, L. H. Kushi, Whole-grain intake and cancer: an expanded review and meta-analysis. *Nutr. Cancer*, 30. (1998) 85–96.

[11] A. Kaukovirta-Norja, P. Lehtinen, Traditional and modern oat-based foods. In: Technology of functional cereal products. B. R. Hamaker (ed.), *Woodhead Publishing Limited, CRC Press*, Cambridge (2008) 215–232.

[12] N. L. Kent, Technology of cereals. *Pergamon Press*, Oxford (1975).

[13] H. G. Marshall, Y. Pomeranz, Buckwheat: Description, breeding, production, and utilization. In: Advances in cereal science and technology. Y. Pomeranz (Ed.), *American Association of Cereal Chemists, Inc.*, St. Paul, Minnesota (1982) 157–210.

[14] L. Marquart, J. L. Slavin, R. G. Fulcher, Whole-grain foods in health and disease. *American Association of Cereal Chemists Inc.*, St. Paul, Minnesota (2002).

[15] N. M. McKeown, J. B. Meigs, S. M. Liu, P. W. F. Wilson, P. F. Jacques, Whole-grain intake is favorably associated with metabolic risk factors for type 2 diabetes and cardiovascular disease in the Framingham Offspring Study. *Am. J. Clin. Nutr.*, 76. 2. (2002) 390–398.

[16] S. D. McMullen, Oats. In: Handbook of Cereal Science and Technology. K. J. Lorenz, K. Kulp (eds.), *Marcel Decker Inc.*, New York (1991) 199–232.

[17] Nestle: Corporate Wellness Unit, *Food and Nutrition Communication*, (2006).

[18] G. S. Robbins, Y. Pomeranz, L. W. Briggle, Amino acid composition of oat groats. *J. Agr. Food Chem.*, 19. (1971) 536–539.

[19] M. Saastamoinen, J. Kumpulainen, S. Nummela, Genetic and environmental variation of oil content and fatty acids composition of oats. *Cereal Chem.*, 66. (1989) 296–300.

[20] K. J. Steadman, M. S. Burgoon, B. A. Lewis, S. E. Edwardson, R. L. Obendorf, Buckwheat seed milling fractions: description, macronutrient composition and dietary fibre. *J. Cereal Sci.*, 33. (2001) 271–278.

[21] C. J. A. Vinkx, & J. A. Delcour, Rye (Secale cereale L) arabinoxylans: A critical review. *J. Cereal Sci.*, 24. (1994) 1–14.

[22] www.healthgrain.com

[23] V. L. Youngs, Oat lipids and lipid-related enzymes. In: Oats: Chemistry and Technology. F. H. Webster (ed.), *American Association of Cereal Chemists*, *Inc.*, St. Paul, Minnesota (1986) 205–226.