Gluten-Free Flours from Different Raw Materials as the Source of Vitamin B₁, B₂, B₃ and B₆

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Summary Gluten-free (GF) products are those with a natural absence or acceptable level (<20 mg/kg) of gluten. They should be a part of a diet for people with gluten-related disorders, like celiac disease. Recently the popularity of a gluten-free diet (GFD) has risen extremely, because a lot of healthy individuals exclude gluten from their menus. According to the literature data on nutritional deficiencies in the GFD, this trend seems to be risky. This paper describes the nutritional value of 14 flours from different GF raw materials from the aspect of B-group vitamin content (B₁, B₂, B₃, B₆). Vitamins were determined using high performance liquid chromatography after enzymatic and acid hydrolysis of the samples. The vitamin contents significantly differed in the analysed flours. The content (in 100 g of the product) of vitamin B₁ ranged from 0.01 mg (amaranth flour) to 0.60 mg (teff flour), vitamin B₂ from 0.03 mg (GF flour with oats) to 0.22 mg (buckwheat flour), vitamin B₃ from below 0.01 mg (amaranth flour) to 6.02 mg (millet flour), and vitamin B₆ from 0.03 mg (acorn flour) to 0.69 mg (amaranth flour). The content of vitamins in the analysed GF flours was also compared to gluten-containing flours. Obtained results indicate that flours from teff, millet, chestnut, buckwheat, and amaranth are better sources of certain B-group vitamins than flours from corn, rice, and some flours with gluten.

Key Words gluten-free, gluten-free diet, vitamin, flour, deficiency

The enormous interest in GF products and GFD caused a significant increase in the number of GF products available on the food market. These are products made not only from the most popular GF raw materials, like rice, corn, potato starch, and GF wheat starch, but also from quite new and less popular crops like amaranth, quinoa, teff, and others. For many years, the absence or elimination of gluten and sensory properties were the most important technological challenges for GF producers. Nowadays, the nutritional value of GF products and GFD are becoming more relevant. Some data on vitamin content in different GF products can be found in the literature, but they refer mainly to the most popular GF raw materials, like rice, corn, potato starch, and GF wheat starch, but also from quite new and less popular crops like amaranth, quinoa, teff, and others. For many years, the absence or elimination of gluten and sensory properties were the most important technological challenges for GF producers. Therefore, the aim of the present study was to: (1) determine the contents of B-group vitamins (B₁, B₂, B₃, B₆) in GF flours and to compare them, taking into account different GF raw materials used for their production. (2) compare the content of vitamins in GF and gluten-containing flours, (3) evaluate the realization of the daily requirements for analysed vitamins by the tested GF flours.

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GF, like all other diets, should be balanced and provide all nutrients. Most of the studies on GFD report that the energy demand is met at a sufficient level, comparable to that of gluten-containing diets. The differences between gluten and GF diets refer to the proportions of the main nutrients and mostly mean the higher content of proteins and fats and lower content of carbohydrates in GFD than in gluten-containing diets. Moreover, many studies indicate mineral and vitamin deficiencies in GFD. Dietary shortcomings may result from the pathogenesis of CD and from the insufficient supply of nutrients with GF products. It may suggest that GF raw materials or final products are less valuable sources of some nutrients than gluten ones. Many studies on GFD conducted in last 40 years report deficiencies of B-group vitamins (e.g. Ref. 11–15), mainly of B₁, B₂, B₉ and B₁₂.

The enormous interest in GF products and GFD caused a significant increase in the number of GF products available on the food market. These are products made not only from the most popular GF raw materials, like rice, corn, potato starch, and GF wheat starch, but also from quite new and less popular crops like amaranth, quinoa, teff, and others. For many years, the absence or elimination of gluten and sensory properties were the most important technological challenges for GF producers. Nowadays, the nutritional value of GF products and GFD are becoming more relevant. Some data on vitamin content in different GF products can be found in the literature, but they refer mainly to the most popular GF raw materials, like rice, corn, potato starch, and GF wheat starch, but also from quite new and less popular crops like amaranth, quinoa, teff, and others. For many years, the absence or elimination of gluten and sensory properties were the most important technological challenges for GF producers. Therefore, the aim of the present study was to: (1) determine the contents of B-group vitamins (B₁, B₂, B₃, B₆) in GF flours and to compare them, taking into account different GF raw materials used for their production. (2) compare the content of vitamins in GF and gluten-containing flours, (3) evaluate the realization of the daily requirements for analysed vitamins by the tested GF flours.
MATERIALS AND METHODS

Materials. Fourteen GF and four gluten-containing flours were purchased in the local (Polish) stores. All products were from two different production batches. GF flours were signed with a Crossed Grain symbol. Selected GF flours mostly consisted of only one raw material. The only exception was GF flour with oats, which besides GF raw materials (corn, potato, oat), contained food additives, such as sugar and sodium carbonate. The list of all analysed GF flours is presented in Table 1.

Standards of thiamine hydrochloride (vitamin B₁) and pyridoxine hydrochloride (vitamin B₆) were purchased from Fluka (Buchs, Switzerland). Pyridoxamine dihydrochloride, pyridoxal hydrochloride (vitamin B₆), riboflavin (vitamin B₂), and nicotinamide (vitamin B₃) were purchased from Sigma (St. Louis, MO). Taka-diastase (α-amylase from Aspergillus oryzae) was purchased from Sigma-Aldrich (Munich, Germany). Methanol of HPLC grade was from Chempur (Piekary Śląskie, Poland). All other chemicals were of analytical grade. Certified Reference Material (CRM) BCR-121 (Wholemeal flour) was from the Institute of Standards and Technology (Gaithersburg, MD). It was used as bottled, without further grinding or sieving.

Extraction procedure. The extraction method consisted of the combination of acid and enzymatic digestion of food samples. The procedure was based on the method described by Viñas et al. (28), but several improvements were introduced. Food samples of 0.5 g

| Table 1. The content of B-group vitamins in gluten-free flours [mg in 100 g]. |
|-------------------------------|----------------|----------------|
| Flour                         | B₁      | B₂      | B₃      | B₆      |
| Traditional                   |         |         |         |         |
| 1 Buckwheat flour (P1)¹       | 0.37±0.02a | 0.22±0.01a | 3.16±0.22a | 0.33±0.01a |
| 2 Buckwheat flour (P2)²       | 0.13±0.01c | 0.06±0.01d | 4.88±0.12  | 0.27±0.02  |
| 3 Chickpea flour              | 0.37±0.02a | 0.12±0.01c | 1.64±0.07c,d | 0.17±0.00b |
| 4 Corn flour (P1)¹            | 0.17±0.02  | 0.15±0.02  | 1.89±0.02b | 0.32±0.01a |
| 5 Corn flour (P2)²            | 0.11±0.01c | 0.06±0.00d  | 1.43±0.07d | 0.11±0.01c,d |
| 6 Millet flour                | 0.40±0.01  | 0.20±0.02b  | 6.02±0.12   | 0.09±0.01d |
| 7 Rice flour (P1)¹            | 0.13±0.01c | 0.13±0.00f  | 1.81±0.06b,c | 0.35±0.01  |
| 8 Rice flour (P2)²            | 0.02±0.00d  | 0.03±0.00e  | 2.34±0.20   | 0.17±0.00b |
| Alternative                   |         |         |         |         |
| 9 Acorn flour                 | 0.02±0.00d | 0.13±0.02c  | nd³         | 0.03±0.00c |
| 10 Amaranth flour             | 0.01±0.00d | 0.04±0.00d,c | <0.01       | 0.69±0.04  |
| 11 Chestnut flour             | 0.24±0.01b | 0.21±0.01a,b | nd³         | 0.18±0.01b |
| 12 GF flour with 10% of oat flour | 0.07±0.01d  | 0.05±0.00d,c | 0.31±0.02d | 0.04±0.01d,e |
| [corn, potato, oat]           |         |         |         |         |
| 13 Oat flour                  | 0.25±0.02c,b  | 0.04±0.00d,e | 0.72±0.10d | 0.10±0.01c,d |
| 14 Teff flour                 | 0.60±0.05  | 0.13±0.01c  | 3.24±0.14d  | 0.12±0.01c |

¹,² Products from different producers. ³ Not determined (coelution with other ingredients). ⁴ Results published in Ref. 42. Mean values with the same letter (a–e) in the column are not significantly different at α=0.05.

| Table 2. Chromatographic conditions of B-group vitamin determinations. |
|-------------------------------|----------------|----------------|
| Vitamin B₁¹                  | Eluent         | methanol/0.05 M CH₃COONa, pH 6.0 (40 : 60)—isocratic |
| Column                       | LiChrospher C₁₈ (250×3.9 mm, 5 µm) |
| Injection                    | 50 µL          |
| Flow                         | 1 mL/min       |
| Detection                    | FL—excitation 365/emission 435 nm |
| Vitamin B₂, B₃, B₆²           | Eluent         | methanol/0.05 M NaH₂PO₄ with 0.005 M hexanesulfonic acid, pH 3.0—gradient |
| Column                       | Nova-Pak C₁₈ (150×3.9 mm, 5 µm) |
| Injection volume             | 50 µL          |
| Flow                         | 1 mL/min       |
| Detection                    | FL—B₂ excitation 450/emission 530 nm, B₆ excitation 290/emission 390 nm, PDA—B₁ 260 nm |

FL, fluorescence detection; PDA, photodiode-array detection. ¹ As described in Ref. 29). ² As described in Ref. 30).
were mixed with 7 mL of 0.05 mol/L ammonium acetate (pH 4.0) and 0.1 mL of 20% taka-diastase. Enzymatic hydrolysis was conducted at 50˚C for 2 h. For acid hydrolysis, 1 mL of 0.6 mol/L hydrochloric acid was added and sample was heated at 90˚C for 1 h. After cooling, samples were filtered and filled up to 25 mL with demineralized water. Samples were prepared daily and wrapped in aluminium foil to avoid the influence of light. Before chromatographic analysis, samples were centrifuged at 14,000 ×g for 5 min (Eppendorf Mini Spin Plus, Eppendorf AG, Germany). Extracts from all samples were prepared in triplicate. For determination of vitamin B1, thiamine was converted into thiochrome derivative using 1% potassium ferricyanide.

**HPLC determination of vitamins.** A high performance liquid chromatograph (HPLC) (Waters 600, Milford, MA) with fluorescence (Waters 774) and photodiode array (Waters 996) detectors was used. Two chromatographic methods were applied for all extracts—one for B1 vitamin (thiamine) (29) and another for B2 (riboflavin), B3 (as nicotinamide), and B6 vitamin (as the sum of pyridoxine, pyridoxamine, and pyridoxal) (30). The conditions for both methods are summarized in Table 2.

Applied methods were verified using Certified Reference Material (CRM) BCR-121 Wholemeal flour (vitamin B1 and B6) and the recovery method (vitamin B2 and B3). The HPLC methods were used for determination of these vitamins. In recent years, the HPLC technique has been most widely used because it provides rapid, accurate, sensitive, and simultaneous analysis of several vitamins. In Figs. 1–3, the separation of vitamins B2, B3, and B6 obtained using the HPLC method employed in the present study (30) is presented. Figure 1 shows the HPLC chromatogram of standards of vitamin B2, B3, and B6. The HPLC chromatograms of CRM and one of the flour samples are shown in Fig. 2 and Fig. 3, respectively. The obtained results of 89% for vitamin B1, 98% for vitamin B2, 92% for vitamin B3, and 92% for vitamin B6 were highly satisfactory and comparable to other studies on B-group vitamins in grain products (31–33).

**RESULTS AND DISCUSSION**

Accuracy of the extraction method confirmed using HPLC

Accuracy of the extraction method was validated using CRM (B1, B6) and recovery method (B2, B3). The HPLC methods were used for determination of these vitamins. In recent years, the HPLC technique has been most widely used because it provides rapid, accurate, sensitive, and simultaneous analysis of several vitamins. In Figs. 1–3, the separation of vitamins B2, B3, and B6 obtained using the HPLC method employed in the present study (30) is presented. Figure 1 shows the HPLC chromatogram of standards of vitamin B2, B3, and B6. The HPLC chromatograms of CRM and one of the flour samples are shown in Fig. 2 and Fig. 3, respectively. The obtained results of 89% for vitamin B1, 98% for vitamin B2, 92% for vitamin B3, and 92% for vitamin B6 were highly satisfactory and comparable to other studies on B-group vitamins in grain products (31–33).

The content of B-group vitamins in GF and gluten flours

Flours were chosen as the products to be analysed, because they properly reflect the content of nutrients in milled grains/pseudocereals (generally they do not contain other ingredients). Moreover, people on GFD often do not buy commercial breads or cakes, because they prepare breadstuff themselves using different GF flours.

In the present study, the classification of tested GF
Flours was introduced taking into account the type of raw material they were made from. Therefore, they were divided into traditional and alternative GF products (Table 1). Traditional GF flours are flours from corn, rice, GF wheat starch, buckwheat, chickpea, and millet. They are made from raw materials, which have been popular and available on the food market for many years. Flours which are less popular and quite new on the market of GF products are defined as alternative flours. They include oat, amaranth, acorn, chestnut, and teff flours. Oat flour is qualified as an alternative GF product, because for many years oats' safety in GFD was questioned (34). Oat-based products with Crossed Grain symbol have been available in Scandinavian countries for several years, but in countries like Poland only since 2013.

The content of B-group vitamins (mean±SD) in selected GF flours is presented in Table 1. In Figs. 4–7, the comparison of the contents of vitamins in traditional and alternative GF flours, as well as in gluten flours from wheat, rye, and barley is shown. The content of analysed B-group vitamins in wheat flours (type 450 and 650) and ryes flours (type 720 and 2000) is based on our own data, and in wheat (type 2000) and barley flours is from other studies (19, 32).

In Fig. 4, the content of vitamin B₁ in GF and gluten flours is presented. The average content of vitamin B₁ in traditional and alternative GF flours was comparable (0.21 and 0.20 mg/100 g, respectively). Among the analysed flours, the highest content of vitamin B₁ was found in teff flour (0.60 mg/100 g). Millet flour (0.40 mg), buckwheat flour from producer P1 (0.37 mg), and chickpea flour (0.37 mg) were also rich in thiamine. The content of thiamine in these flours was comparable to its content in wheat flour (type 2000) and barley flour (0.43 and 0.36 mg of thiamine in 100 g, respectively). Oat and chestnut flours, with 0.24–0.25 mg of vitamin in 100 g, were similar to rye flours (type 720 and 2000; 0.22 and 0.25 mg/100 g, respectively). The content of vitamin B₁ in other GF flours—corn P1 (0.17 mg), rice P1 (0.13 mg), buckwheat P2 (0.13 mg), corn P2 (0.11 mg), and GF with oats (0.07 mg)—was com-
B-Group Vitamins in Gluten-Free Flours

The average content of vitamin B2 (Fig. 5) in all selected traditional GF flours (0.12 mg/100 g) was comparable to its content in alternative flours (0.10 mg/100 g). The content of vitamin B2 in three GF flours (buckwheat P1, chestnut, and millet), which were found to be the richest in vitamin B2 among the tested GF flours (0.20–0.22 mg/100 g), was slightly higher than in the richest in B2 gluten flour (wheat flour type 2000 with the content of 0.17 mg/100 g). Flours from corn P1, rice P1, chickpea, acorn, and teff (0.12–0.15 mg/100 g) were similar to barley flour and rye flour type 2000 (0.14 mg). Flours from amaranth, oats, buckwheat, and corn from producer P2 (0.04–0.06 mg/100 g) were similar to wheat flours of type 450 and 650 (0.06 mg/100 g). The lowest content of riboflavin (≤0.04 mg in 100 g) was found in amaranth flour, rice flour P2, oat flour, and GF flour with oats.

The highest content of vitamin B3 (Fig. 6) was found in traditional GF flours: millet (6.02 mg/100 g) and buckwheat P2 flour (4.88 mg/100 g). The whole group of traditional flours contained on average almost 3-fold more niacin (2.90 mg/100 g) than alternative flours (1.07 mg/100 g). Barley flour, with 4.07 mg of niacin, was also an important source of this vitamin. The content of B3 in buckwheat P1 and teff flours (about 3.20 mg/100 g) was slightly higher than its content in wheat flour type 2000 (2.80 mg/100 g). The content of vitamin B3 in flours from rice P1 and P2, corn P1 and P2, and chickpea was between 1.43 and 2.34 mg/100 g. Less vitamin B3 was found in gluten flours: wheat (type 650), rye (type 720), and wheat (type 450)—1.06, 0.86, 0.58, and 0.52 mg/100 g, respectively and in oat flour (0.72 mg/100 g). The least valuable source of vitamin B3 were GF flour with 10% of oat flour (0.31 mg/100 g) and amaranth flour (<0.01 mg/100 g). The niacin determination in two alternative flours (acorn and chestnut) was impossible, because of its coelution with other ingredients (the UV spectrum of vitamin B3 in extracts from these products was unclear; thus we decided not to determine it).

The average content of vitamin B6 (Fig. 7) in traditional GF flours was 0.23 mg and in alternative GF flours was 0.19 mg in 100 g. Amaranth flour (0.69 mg/100 g) was the richest source of vitamin B6 from all the analysed flours. The content of vitamin B6 in flours from rice, corn, and buckwheat flour from producer P1 (0.32–0.35 mg/100 g) was comparable to the vitamin content in wheat flour type 2000 (0.34 mg/100 g), whereas that in buckwheat P2 flour (0.27 mg/100 g) was comparable to barley flour (0.26 mg/100 g). Most of the analysed GF flours, i.e. chickpea, corn, teff, rye P2, chestnut, oat, barley flour (0.26 mg/100 g) were similar to gluten-containing flours from wheat (type 450 and 650) and rye (type 720 and 2000) (0.12–0.16 mg/100 g). The lowest content of vitamin B6 was found in two GF flours: that with 10% of oats (0.04 mg/100 g) and acorn (0.03 mg/100 g).

The content of analysed vitamins in some GF flours was comparable to or lower than in flours from wheat, rye, and barley. Although it is impossible to indicate flours with a high content of all analysed water-soluble vitamins, several products can be indicated as a good source of certain vitamins. They were made from both traditional and alternative GF raw materials such as teff, buckwheat P1, chickpea, and millet (rich in B1), chestnut (rich in B2), amaranth flour (rich in B6), buckwheat P1 and millet flour (rich in B2 and B3). These flours should be implemented both in GF and gluten-containing diets.

It should be noticed that some differences between the same products from different producers were found. Mostly, analysed GF flours from producer P1 contained more analysed vitamins than products offered by the manufacturer P2. These differences may result from the contents of vitamins in a raw material and from different milling techniques.

The realization of Recommended Daily Allowance for B-group vitamins by GF flours

The obtained results are expressed as the percentage of Recommended Daily Allowance (RDA) realized by 100 g of each flour to indicate the influence of consumption of GF flours on the realization of RDA for tested vitamins. RDA values for vitamins (valid in such countries as Poland, the United States, and Canada) are established at the levels for a model person (female, at the age of 40)—1.1 mg, 1.1 mg, 14 mg, and 1.3 mg for vitamin B1, B2, B6, and B3, respectively. Epidemiological studies indicate that CD affects twice as many women as men (35). Another important gluten-related disorder—Düühring disease (Dermatitis herpetiformis), in which it is necessary to introduce a GF diet—affects more frequently adults than children, as well as women than men (36). Therefore, a middle-aged woman was selected as the model person. The choice of another model person (a man or child) will not change the relationship of RDA between tested products. RDA levels differ in the world; these presented are applied in Poland and the United States (37, 38).

In Table 3, the realization of RDA for analysed vitamins by a 100 g portion of GF flour is presented. The classification of products as those realizing a very high/ high/medium/low percentage of RDA for vitamin B1, B2, B3, and B6 reflects their nutritional value. The very high percentage refers to ≥50%, high ≥30% <50%, medium ≥10% <30%, and low <10% of the realization of RDA by 100 g of flour.

Among all the selected flours only two were classified as those with a very high impact on RDA realization (Table 3). These were 100 g portions of teff flour, which realized 54% of the RDA for vitamin B1, and amaranth flour with 53% of the RDA for vitamin B6. None of analysed flours were found to have a very high impact on the RDA realization for vitamin B2 or B3; or a high impact on RDA realization for vitamin B1 or B6. Grain products are basically not a good source of the latter vitamins. Other
Table 3. The realization of RDA [in%] for analysed vitamins by 100 g of gluten-free flours.

| The realization of RDA by gluten-free flours |  |  |
|---|---|---|
| For vitamin B₁ [1.1 mg₁] |  |  |
| Very high² | teff flour | 54% |
| High¹ | millet flour | 36% |
| chickpea flour | 33% |
| buckwheat flour P₁ | 33% |
| Medium⁴ | oat flour | 23% |
| chestnut flour | 21% |
| corn flour P₁ | 15% |
| rice flour P₁ | 12% |
| buckwheat flour P₂ | 12% |
| corn flour P₂ | 10% |
| Low⁵ | GF flour with oats, rice flour P₂, acorn flour, amaranth flour | <10% |
| For vitamin B₂ [1.1 mg₁] |  |  |
| Very high² | — | — |
| High¹ | — | — |
| Medium⁴ | buckwheat flour P₁ | 20% |
| chestnut flour | 19% |
| millet flour | 18% |
| corn flour P₁ | 14% |
| acorn flour | 12% |
| rice flour P₁ | 12% |
| teff flour | 12% |
| chickpea flour | 11% |
| Low⁵ | buckwheat flour P₂, corn flour P₂, amaranth flour, rice flour P₂, oat flour, GF flour with oats | <10% |
| For vitamin B₃ [14 mg₁] |  |  |
| Very high² | — | — |
| High¹ | millet flour | 43% |
| buckwheat flour P₂ | 35% |
| Medium⁴ | teff flour | 23% |
| buckwheat flour P₁ | 23% |
| rice flour P₂ | 14% |
| corn flour P₂ | 13% |
| rice flour P₁ | 13% |
| chickpea flour | 12% |
| corn flour P₁ | 10% |
| Low⁵ | oat flour, GF flour with oats, amaranth flour | <10% |
| For vitamin B₆ [1.3 mg₁] |  |  |
| Very high² | amaranth flour | 53% |
| High¹ | — | — |
| Medium⁴ | rice flour P₁ | 27% |
| buckwheat flour P₁ | 25% |
| corn flour P₁ | 25% |
| buckwheat flour P₂ | 21% |
| chestnut flour | 14% |
| chickpea flour | 13% |
| rice flour P₂ | 13% |
| Low⁵ | teff flour, oat flour, millet flour, GF flour with oats, acorn flour, amaranth flour | <10% |

¹ RDA for vitamins in Poland/US/Canada. ², ³, ⁴, ⁵ Explanation of the very high/high/medium/low is clarified in the main text (section: The realization of Recommended Daily Allowance for B-group vitamins by GF flour).

good sources of thiamine and niacin were millet flour, chickpea flour, and buckwheat flour P₁ (33–36% of RDA for thiamine) and millet flour and buckwheat flour P₂ (35–43% of RDA for niacin). Buckwheat flour from P₁ was also a medium source of vitamin B₂, B₁, and B₆ (20%, 23% and 25%, respectively), whereas chestnut flour was a medium source of vitamin B₁, B₂, and B₆ (23%, 19% and 14%, respectively).

It is not easy to introduce to the everyday menu a 100 g portion of flour from teff or amaranth, mainly because of their characteristic flavour and smell, but also because of their price, which is up to several times
higher than price of flours from the most popular rice and corn. A good solution, from nutritional, economic and organoleptic points of view, is substitution of some part, e.g. 20%, of traditional GF flour, with these flours when preparing bread or cookies. Moreover, consumption of different crops, like buckwheat or oats, has other positive effects on health, e.g. hypcholesterolemic and anticancerous, as was indicated by Giménez-Bastida and Zielinski (39), and Rasane et al. (40).

CONCLUSIONS

The analysed GF flours significantly differed in the content of B-group vitamins. The highest content of B-group vitamins was found in traditional and alternative GF flours: in teff flour (B1), buckwheat flour P1 and chestnut flour (B2), millet flour (B2 and B3), buckwheat flour P2 (B3), and amaranth flour (vitamin B6). From a nutritional point of view only two selected flours were classified as those of a very high impact on RDA realization for certain vitamins. These were 100 g portions of teff flour, which realized 54% of the RDA for vitamin B1, and amaranth flour with 53% of the RDA for vitamin B6. None of the analysed flours was found to have a very high impact on the RDA realization for vitamin B2 or B3. With high, between 30% and 50%, impact on the RDA were millet flour (vitamin B1 and B3), chickpea flour and buckwheat P1 (vitamin B3) and buckwheat P2 (vitamin B3). These flours should be a part of a GFD, as well as a gluten-containing diet.

The presented results may be helpful for people on a GFD, dietitians, and food technologists, as well as for food producers. The obtained results can indicate how consumers and producers may increase the nutritional value of meals and products based on GF cereals or pseudo-cereals. Similar recommendations, which assume nutritional value of meals and products based on GF cereals or pseudo-cereals. Similar recommendations, which assume food producers. The obtained results can indicate how consumers and producers may increase the nutritional value of meals and products based on GF cereals or pseudo-cereals. Similar recommendations, which assume inclusion of products from quinoa, buckwheat, teff, and amaranth have been lately published by Pellegrini and Agostoni (41).

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