Pol. J. Food Nutr. Sci., 2013, Vol. 63, No. 1, pp. 5-10
DOI: 10.2478/v10222–012–0067–3
http://journal.pan.olsztyn.pl

Original paper
Section: Food Quality and Functionality

Protein Quality of Traditional Rye Breads and Ginger Cakes as Affected by the Incorporation of Flour with Different Extraction Rates

*Elena Peñas[1], Cristina Martinez-Villaluenga[1], Concepción Vidal-Casero[1], Henryk Zieliński[2], Juana Frias[1]**

[1]Institute of Food Science, Technology and Nutrition (ICTAN-CSIC), Juan de la Cierva 3, 28006 Madrid, Spain
[2]Division of Food Science, Institute of Animal Reproduction and Food Research of Polish Academy of Sciences, Tuwima 10, P.O. Box 55, 10–747 Olsztyn 5, Poland

Key words: rye bread, ginger cake, flour extraction rate, amino acid composition, protein quality

The aim of this study was to evaluate the effect of rye flour extraction rate on the protein amino acids content and protein quality indexes (chemical score, CS, protein efficiency ratio, PER) of traditional rye bread and ginger cake and to compare them with conventional wheat bread. Rye flour with extraction rates of 1000 g/kg and 920 g/kg (F-1000 and F-920, respectively), were used. Amino acid content was determined by HPLC and protein quality indexes were calculated. The results showed that contents of non-essential amino acids (NEAA) were not much affected by flour extraction rate in rye bread and ginger cake since only Asp and Ser were higher in F-1000 rye bread and Arg and Pro in F-1000 ginger cake. In regard to essential amino acids (EAA), only Thr and Val content was significantly higher ($P \leq 0.05$) in F-1000 rye bread, on dry weight basis. In addition, rye bread formulated with whole rye flour exhibited a higher content of total EAA than wheat bread ($P \leq 0.05$). Regarding protein quality indexes, CS values were quite low in breads and ginger cakes, being Lys the limiting amino acid. However, estimated PER values were similar among wheat and rye breads, and slightly lower for ginger cakes. Hence, whole rye flour should be considered as an approach to improve the nutritional quality of traditional rye-based products.

INTRODUCTION

Rye (*Secale cereale* L.) is nowadays the second most used grain for bread making and it is likely to gain interest and popularity [Andlauer & Furst, 1999; Bushuk, 2001]. According to FAO web page (http://www.faostat.fao.org/site/339/default.aspx; 8 October 2012), the production of this cereal is approximately 15.7 million tonnes in the world, and this accounts for almost 92% of its production in Europe. The use of rye is of great interest because of its better nutritional quality compared to wheat baked goods in terms of higher dietary fiber, notably arabinoxylan and β-glucan, which are beneficial to health for their ability to lower postprandial serum glucose levels and insulin response and to lower serum cholesterol levels [Brennan & Cleary, 2005]. Furthermore, rye seed storage proteins have a relatively high lysine content compared with wheat and are, therefore, of better nutritional quality [Bushuk, 2001]. Rye is also rich in potential chemopreventive compounds including folate, phenolic acids, alkylresorcinols (phenolic lipids), and sterols [Nyström *et al*., 2008].

As flour, rye is used in bread and many other baked products such as ginger cakes. For human consumption, rye grain must be milled which modifies grain composition and properties. Various types of flour can be obtained by milling process possessing different proportions of the original rye that is finally converted to flour (extraction rate). Rye flour extraction rates decrease as function of the amount of grain outer layers removed. Commonly, whole (extraction rate of 1000 g/kg), brown (extraction rates of 850–980 g/kg) and white (extraction rates of 720–800 g/kg) rye flours are employed for rye bread making being the whole flour the most extensively used. Several studies have shown that the extraction rate impacts sensory and nutritional quality of rye-baked goods. Nutritionists worldwide recommend consumption of whole grain products and dietary fibre [Adams & Engstrom, 2000]. Zielinski *et al*. [2008] reported higher sensory quality for whole meal rye bread compared to bread made from brown rye flour. The final appearance and taste of breads were dependent on flour extraction rates taken for dough formulation [Michalska *et al*., 2008; Horszwald *et al*., 2010]. In addition, rye products made from whole grain flours contain higher dietary fiber, antioxidant capacity, and health-promoting compounds [Michalska *et al*., 2007; Zielinski *et al*., 2010; Capuano *et al*., 2010].

Rye breads and ginger cakes are a good example of traditional food in Central Europe which reflects cultural inheritance. In Poland, the total consumption of bread is 71 kg per year and person, being rye bread 5%, wheat bread 19.2%, and the rest are related to wheat/rye mixed breads [Piekut, 2008]. The total consumption of ginger cakes is difficult to estimate as this type of bakery product is eaten occasionally, mainly due to the Christmas period, however is available dur-

* Corresponding Author: Tel.: +34 912587510; Fax: +34 915644853; E-mail: frias@ictan.csic.es

ing whole year from the markets. Recently, we showed that rye flour extraction rates, formulation and baking process affected Maillard reaction development and antioxidant capacity of rye breads and ginger cakes [Michalska *et al*., 2008; Zieliński *et al*., 2010]. To the best of our knowledge, no information related to the effect of flour extraction rate on the protein quality of rye-baked products has been reported so far. Therefore, this study was aimed at exploring the effect of rye flour extraction rate on protein quality of rye baked goods such as rye bread and ginger cakes. Protein quality was evaluated by the analysis of the protein amino acid profile and the calculation of chemical score (CS) and protein efficiency ratio (PER) of the traditional rye-based products. Comparisons with conventional wheat bread were also performed.

MATERIALS AND METHODS

Chemicals

Amino acid standard AA-18, DL-norleucine, ammonium acetate, tryptophan and phenylisothiocyanate 99% (PITC) were purchased from Sigma-Aldrich (Diesenhoffen, Germany). Methanol and acetonitrile of liquid chromatography grade were supplied by Scharlab (Madrid, Spain). Any other reagents were of analytical grade. Water was purified with a Milli-Q system (Millipore, Bedford, USA).

Materials

Rye grains cv. Warko were obtained from a plant breeding station in central Poland (DANKO Plant Breeding, Laski, Poland). Samples were tempered to 14% moisture and milled on a Quadrumat Senior equipment (Brabender, Duisburg, Germany) to obtain flour with extraction rates of 1000 g/kg (whole meal flour) and 920 g/kg (brown flour). White wheat flour, baker's yeast, floral honey, sodium bicarbonate and sugar were purchased at a local market in Olsztyn, Poland.

Rye bread and ginger cake making process

Rye breads were formulated on whole meal (extraction rate 1000 g/kg; F-1000) and brown (extraction rate of 920 g/kg; F-920) rye flours, respectively. Rye breads were produced at a pilot-scale bakery using traditional sourdough fermentation with baker's yeast addition as shown in Figure 1. At the first stage, sourdough starter was prepared by mixing 36% of the respective rye flour and 64% of water. This mixture was fermented for 48 h at 28°C. At the second stage, sour was prepared by mixing 300 g of sourdough starter, 300 g of each type of rye flour, 300 mL of water and 10 g of yeast. This mixture was fermented for 3 h at 28°C. The third stage consisted of mixing 800 g sour, 600 g of the respective rye flour, 300 g of water and 20 g of salt, an then the dough was left for final fermentation for 30 min at 28°C in a fermentation chamber. Dough pieces (350 g) were molded by hand, panned and proofed for 45 min at 28°C (75% relative humidity). Wheat bread formulated with white wheat flour (extraction rate 700 g/kg) was prepared using the single phase method, and used as reference. Breads were baked at 260°C for 40 min in an electric oven model DC-32E (Sveba-Dahlen, Fristad, Sweden). Breads were cut into slices of 1 cm thickness. At least 4 units of each type of bread were made.

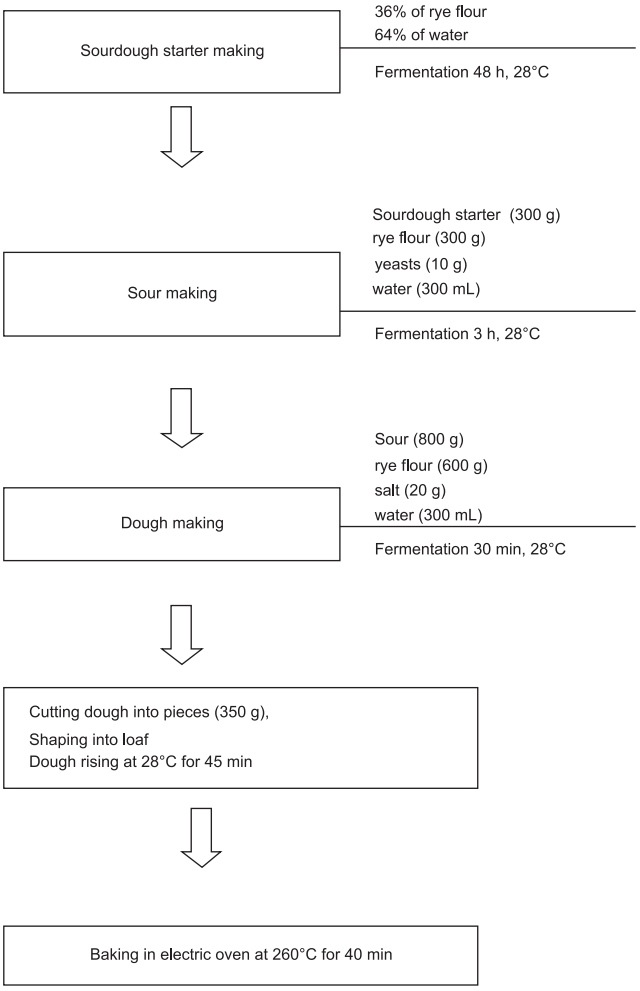

FIGURE 1. Simplified flow diagram of rye bread making process.

Similarly to rye breads, ginger cakes were made from whole meal (F-1000) and brown (F-920) rye flours. The traditional ginger cake-making process involved dough preparation by mixing flour, honey and sugar in the ratio shown in Table 1. Ginger cake doughs were stored at 20–22°C for 5 days. Afterwards, sodium bicarbonate and ginger spices were added. The dough was cut into 0.5-cm thick discs of 5.5 cm diameter that were baked at 180°C for 18 min in a DC-32E electric oven (Sveba-Dahlen, Fristad, Sweden). At least 20 units of each type of ginger cakes were made.

Rye breads and ginger cakes were freeze-dried and ground. Powdered samples were stored at -20°C in hermetic bags sealed under vacuum for further analysis.

TABLE 1. Formulation of traditional ginger cakes made up of whole meal (F-1000) and brown (F-920) rye flour,

Ingredient (g)	Ginger cake (F–1000)	Ginger cake (F–920)
Whole meal rye flour (F–1000)	500	0
Brown rye flour (F-920)	0	500
Honey	200	200
Sugar	250	250
Baking soda	15	15
Ginger spice	40	40

Analysis of moisture and protein content

Nitrogen content was determined according to the Kjeldahl method AOAC 984.13 [AOAC, 1990] and nitrogen value was multiplied by 6.25 as conversion factor to calculate protein content [AOAC, 1990]. Moisture content was analysed according to AOAC 15.950.01 [AOAC, 1990]. Analyses were performed in triplicate.

Analysis of protein amino acids

Sample preparation was carried out by acid hydrolysis and subsequent amino acid derivatization as reported previously [Martínez-Villaluenga *et al*., 2008]. Briefly, 200 μL of DL-norleucine (200 μmol/mL) were added to 100 mg of the sample as an internal standard. Protein hydrolysis was performed by addition of 2 mL of 6 N HCl and incubation at 110ºC in a vacuum-closed vial for 21 h. Acid hydrolysates were dried under vacuum and rinsed twice with water. For amino acid derivatization, PITC was used. Amino acids were analysed by HPLC with a photodiode array detector settled at 254 nm on an Alliance Separation Module 2695 (Waters, Milford, USA). Data acquisition and processing were performed with Empower version 2 (Waters, Milford, USA). The separation of amino acids was carried out with an Alltima C_{18} column (250 x 4.6 mm, 5 μm particle size) (Grace, Deerfield, IL, USA) connected to a guard column (Grace). Injection volume was 20 mL. The elution, at a flow rate of 1 mL/min, was in gradient at 43ºC using a combination of two eluents: A (0.1 mol/L ammonium acetate, pH 6.5) and B (0.1 mol/L ammonium acetate/acetonitrile/methanol; 44/46/10; v/v/v, pH 6.5). The gradient used was 100% A from 0 to 15 min, 90% A and 10% B from 15 to 30 min, 60% A and 40% B from 30 to 40 min, 50% A and 50% B from 40 to 50 min. After each run, the column was washed for 10 min with 100% B and re-equilibrated for 15 min with the starting conditions of the employed gradient.

For the analysis of tryptophan, alkali hydrolysis was performed by addition of 2 mL of 4.2 N NaOH to 100 mg of sample and incubation at 110ºC in a vacuum-closed vial for 21 h, as described in the AOAC 988.15 method [AOAC, 1990]. Hydrolysates were adjusted to pH 4.25. Tryptophan was quantified by HPLC with a photodiode array detector settled at 280 nm on an Alliance Separation Module 2695 (Waters, Milford, USA). Data acquisition and processing were performed with Empower version 2 (Waters, Milford, USA). Sample (20 mL) was injected onto a μBondapak C_{18} column (250 x 4.6 mm, 10 μm particle size) (Waters, Milford, USA). Mobile phase consisted of 0.0085 mol/L sodium acetate/methanol (95:5, v/v) and eluted at room temperature in isocratic mode at a flow rate of 1 mL/min for 20 min.

Amino acids were identified by comparing their retention times with those of standard amino acids. Quantitative analysis was performed by the external and internal calibration, using standard concentrations ranging from 0.1 to 1 mmol/L ($R^2 > 0.99$). Analyses were carried out in triplicate.

Protein quality indexes

Chemical score (CS) was achieved by a comparison of the content of the main limiting amino acid in breads and ginger cakes with its content in the requirement pattern [Pellet & Young, 1980]. This index represents an accurate approximation to the biological value when a selected protein reference is used to compare with a corresponding age group. In this work, CS was calculated as the average of the ratio of each essential amino acid in the tested food protein, expressed in g/100 g protein, to their respective content in the recommended protein reference pattern for 3–10 year old children, according to FAO [2007]:

$$CS = (\text{Limiting amino acid of test protein/the same amino acid of reference protein}) \times 100$$

The amino acid with the lowest percentage is called the limiting amino acid and this percentage is considered the chemical score.

Protein efficiency ratio (PER) was calculated as according to Alsmeyer *et al*. [1974]. These authors proposed an equation predicting protein usability which is expressed in terms of concentrations of only two amino acids -leucine and tyrosine-, based on experiments on their availability/digestibility:

$$PER = -0.468 + 0.454Leu - 0.105\ Tyr$$

where Leu and Tyr are the concentrations of these amino acids of tested protein expressed in g/100 g of protein.

Statistical analysis

Data were obtained from three independent experiments each analysed in triplicate. Data were expressed as the mean ± standard deviation of three independent experiments. Differences between samples were tested using one-way ANOVA, followed by a least significance difference (LSD) test as a post-hoc comparison of means ($P \leq 0.05$). Statistical analyses were performed using Statgraphic for Windows version 5.0 (Statistical Graphic, Rockville, MD., USA).

RESULTS AND DISCUSSION

Moisture and total protein content

Table 2 shows the content of dry matter and total protein in rye breads and ginger cakes with different flour extraction rates in comparison with conventional wheat bread. Breads made from whole meal (F-1000) and brown (F-920) rye flours exhibited a significantly similar dry matter content as wheat bread, in a range of 725–766 g/kg, and a lower content than ginger cakes 966 g/kg ($P \leq 0.05$). These differences were mainly due to the dif-

TABLE 2. Dry matter and protein content of rye breads and ginger cakes formulated with whole meal (F-1000) and brown (F-920) rye flours.

Material	Dry matter*	Protein content**
Rye bread (F-1000)	725.0±12.3^a	103.2±0.1^c
Rye bread (F-920)	748.0±9.6^a	102.0±0.1^b
Ginger cake (F-1000)	966.5±21.5^b	64.8±0.3^a
Ginger cake (F-920)	966.0±17.8^b	63.6±0.9^a
Wheat bread	766.0±11.3^a	123.2±0.3^d

Results are the mean ± standard deviation of three independent experiments. Different superscripts in the same column indicate significant difference ($P \leq 0.05$, one-way ANOVA). *Data are expressed in g/kg. ** Data are expressed in g/kg dw.

ferent formulation of breads and ginger cakes and baking temperature and time used (Table 1 and Figure 1). Rye breads made up of whole meal rye flour (F-1000) contained a slightly higher protein content (P≤0.05) than those formulated on brown rye flour (F-920). However, ginger cakes presented a similar (P>0.05) protein content, irrespective of the flour extraction rate. As expected, rye bakery products contained significantly lower (P≤0.05) protein content than control wheat bread (Table 2). Horszwald *et al*. [2009] indicated that extraction rates could affect the protein profile and distribution of protein content in different parts of rye breads: slices, crusts and crumbs. In the present study, we noted that rye bread formulated with whole meal flour (F-1000) provided the highest protein content as compared to other bakery products. On the other hand, to our knowledge, no information has been recorded about protein content of ginger cakes formulated with different rye flour extraction rates.

Total protein amino acid composition of rye breads and ginger cakes

The amino acid composition of traditional rye breads and ginger cakes made up of whole meal (F-1000) and brown (F-920) rye flours as well as those of conventional wheat bread expressed as g/100 g dry weight (dw) is collected in Table 3. Among the non-essential amino acids (NEAA), Glu and Pro were present in the highest amounts whilst Leu and Phe were the predominant essential amino acids (EAA) found in rye breads and ginger cakes. The first and second limiting amino acids in the rye bakery products were Trp and Lys. Rye breads formulated with whole rye flour (F-1000) showed a significant higher content of Asp, Ser, Thr and Val (P≤0.05) than rye bread F-920. As a consequence, rye bread F-1000 exhibited higher content of total NEAA and EAA than rye bread F-920 (Table 3). Differently, the use of whole meal rye flours in the formulation of ginger cakes increased the content Arg and Pro (P≤0.05) resulting in a slightly higher content of total NEAA (Table 3). Results suggest that flour extractability affected slightly the protein amino acid content of rye bakery products. Nevertheless, taking into account the amount of amino acids provided by a portion of 100 g on dry weight basis, rye products contained a significantly (P≤0.05) similar content of total EAA than wheat bread which provided significantly lower amounts of Phe and His, but higher amounts of Leu and Lys (P≤0.05) (Table 3). At the same time, ginger cakes provided lower amounts of NEAA and EAA for the same portion (Table 3), mainly due to ginger formulation consisting of lower amounts of rye flour and the inclusion of other ingredients such as honey and sugar (Table 1). No information related to protein amino acid in traditional rye breads has been published so far.

Lys is the limiting amino acid in most cereal products and during baking it is believed that Maillard reactions may affect content and composition of related products lowering its availability [Charissou *et al*., 2007], but also taking part on

TABLE 3. Amino acid content of wheat and rye breads and ginger cakes formulated with whole meal (F-1000) and brown (F-920) rye flour*.

Amino acids	Wheat bread	Rye bread F-1000	Rye bread F-920	Ginger cake F-1000	Ginger cake F-920
Non essential amino acids (g/100 g dw)					
Asp	$0.56\pm0.04^{a}_{2}$	0.61 ± 0.04^{b}	0.47 ± 0.04^{a}	$0.23\pm0.02_{1}$	$0.22\pm0.02_{1}$
Glu	$4.73\pm0.20^{b}_{2}$	2.47 ± 0.18^{a}	2.14 ± 0.14^{a}	$1.23\pm0.06_{1}$	$1.30\pm0.04_{1}$
Ser	$0.50\pm0.04^{ab}_{2}$	0.43 ± 0.04^{b}	0.38 ± 0.03^{a}	$0.15\pm0.02_{1}$	$0.17\pm0.02_{1}$
Gly	$0.39\pm0.02^{a}_{2}$	0.73 ± 0.04^{b}	0.76 ± 0.07^{b}	$0.16\pm0.04_{1}$	$0.14\pm0.04_{1}$
Arg	$0.35\pm0.02^{a}_{3}$	0.38 ± 0.02^{a}	0.32 ± 0.03^{a}	$0.24\pm0.02_{2}$	$0.10\pm0.01_{1}$
Ala	$0.35\pm0.02^{a}_{2}$	0.30 ± 0.03^{a}	0.29 ± 0.02^{a}	$0.13\pm0.01_{1}$	$0.14\pm0.01_{1}$
Pro	$1.11\pm0.06^{a}_{3}$	0.99 ± 0.05^{a}	0.95 ± 0.05^{a}	$0.36\pm0.02_{2}$	$0.31\pm0.01_{1}$
Total NEAA	7.99	5.91	5.31	2.61	2.40
Essential amino acids (g/100 g dw)					
Ile	$0.43\pm0.02^{a}_{2}$	0.47 ± 0.02^{b}	0.44 ± 0.05^{ab}	$0.15\pm0.04_{1}$	$0.15\pm0.02_{1}$
Leu	$0.98\pm0.04^{b}_{2}$	0.85 ± 0.04^{a}	0.80 ± 0.06^{a}	$0.47\pm0.06_{1}$	$0.42\pm0.06_{1}$
Lys	$0.31\pm0.03^{b}_{2}$	0.22 ± 0.02^{a}	0.18 ± 0.02^{a}	$0.08\pm0.02_{1}$	$0.09\pm0.02_{1}$
Met+Cys	$0.35\pm0.04^{a}_{2}$	0.30 ± 0.01^{a}	0.27 ± 0.02^{a}	$0.13\pm0.02_{1}$	$0.11\pm0.01_{1}$
Tyr	$0.31\pm0.01^{a}_{2}$	0.34 ± 0.03^{b}	0.28 ± 0.03^{ab}	$0.10\pm0.03_{1}$	$0.10\pm0.01_{1}$
Phe	$0.82\pm0.02^{a}_{2}$	0.99 ± 0.07^{b}	0.92 ± 0.03^{b}	$0.31\pm0.07_{1}$	$0.27\pm0.02_{1}$
Thr	$0.52\pm0.02^{c}_{2}$	0.35 ± 0.02^{b}	0.25 ± 0.02^{a}	$0.18\pm0.03_{1}$	$0.18\pm0.02_{1}$
Trp	$0.17\pm0.01^{a}_{2}$	0.18 ± 0.01^{a}	0.19 ± 0.01^{a}	$0.06\pm0.01_{1}$	$0.06\pm0.01_{1}$
Val	$0.52\pm0.03^{a}_{3}$	0.58 ± 0.03^{b}	0.51 ± 0.04^{a}	$0.23\pm0.03_{1}$	$0.19\pm0.02_{1}$
His	$0.21\pm0.01^{a}_{2}$	0.27 ± 0.03^{b}	0.25 ± 0.02^{b}	$0.11\pm0.01_{1}$	$0.10\pm0.01_{1}$
Total EAA	4.66	4.51	4.08	1.81	1.68

*) Data are the mean ± standard deviation of three independent experiments. Different superscripts in the same row indicate significant difference (P ≤ 0.05, one-way ANOVA) among wheat and rye breads. Different subscripts in the same row indicate significant difference (P ≤ 0.05, one-way ANOVA) among wheat bread and ginger cakes. NEAA: Non essential amino acids, EAA: Essential amino acids.

the antioxidant capacity properties [Michalska *et al*., 2007]. In addition, rye breads provide higher phenolics content than wheat rolls and the content was extraction rate-dependent [Michalska *et al*., 2007; Zieliński *et al*., 2008]. In addition, a similar trend was noted in respect to bioactive compounds which may contribute to the health promoting properties of these bakery products.

Protein quality evaluation of rye breads and ginger cakes

Tables 4 and 5 show the protein quality evaluation based on the content of essential amino acids, expressed as g/100 g protein, as well as the percentage of individual amino acid in each rye product *vs.* the requirements for children between 3–10 years [FAO, 2007]. These tables also collect protein quality parameters of rye breads and ginger cakes as chemical score (CS) and estimated protein efficiency ratio (PER) calculated by chemical indexes. Interestingly, both traditional rye breads (F-1000 and F-920) were a better source of EAA compared to wheat bread which contained lower amount of Ile, Tyr, Trp and Val (Table 4). However, Lys content was rather lower, counted as limiting amino acid, and it did not cover 100% of infant requirements. The percentages of other EAA outweigh the values required by 3–10 years old children, with exception of Thr in brown rye bread (F-920) where it was close to the requirement limit. CS for whole meal rye bread was higher (45) than brown rye bread (36), however, these values were lower compared to the CS of wheat bread (53). The calculated PER was not noticeably different for the rye breads (2.94 and 2.79, for F-1000 and F-920, respectively), than for wheat breads (2.88) (Table 4), contributing to the body performance.

Ginger cakes exhibited two-fold lower total EAA than rye and wheat breads in the protein content basis, being Leu and Phe+Tyr the most abundant amino acids and Trp and Lys as the minority ones. Again, Lys was the limiting amino acid, although Met+Cys, Val and His did not reach the recommended requirements for infants (Table 5). CS for these sweet bakery products was very low (25 and 31 for ginger cakes F-1000 and F-920, respectively). In contrast, ginger cake formulated with whole meal rye flour (F-1000) had a higher PER (2.69) than ginger cake made up of flour F-920 (2.36). For this reason, consumption of traditional ginger cakes as typical whole meal rye product could contribute better to the recommended intake of essential amino acids.

The results confirm that protein amino acids in traditional rye-based products are slightly affected by flour extraction rate. However, other factors affecting amino acid composition of traditional rye bread and ginger cake such as differences in bread and cake composition, making process including both dough fermentation, baking time and temperature should be also considered [Mustafa *et al*., 2007]. At the same time, although bakery products are considered a weak source of protein, demonstrated by the CS, they can contribute to the body performance, shown by the estimated PER and, as it has been reported in previous papers, they are well accepted by consumers and are a source of health promoting compounds [Michalska *et al*., 2007; Zielinski *et al*., 2008, 2012].

SUMMARY AND CONCLUSIONS

Whole meal flour appears as a simple and efficient/useful strategy to obtain enhanced value rye-based baked goods such as bread and ginger cakes. In this study we showed that traditional rye breads were a better source of essential amino acids on the protein content basis when compared to conventional wheat bread. The first and second limiting amino acids in rye breads and ginger cakes were Trp and Lys, and CS was rather low. However, based on the calculated protein efficiency ratio, rye bakery products formulated on whole meal flour (F-1000) may contribute to body performance and should be considered as an approach to improve the nutritional quality of traditional rye-based products.

ACKNOWLEDGEMENTS

These studies were supported by AGL2010–16310 project from the Ministerio de Ciencia e Innovación (Spain) and RE-

TABLE 4. Protein evaluation of wheat, whole rye (F-1000) and brown rye (F-920) breads by chemical indexes.

Essential amino acids	Requirements for 3–10 years old children **	Wheat bread*	% Amino acid wheat bread/ requirements	Rye bread F-1000*	% Amino acid rye bread F-1000 / requirements	Rye bread F-920*	% Amino acid rye bread F-920 / requirements
Ile	3.1	3.81	123	4.52	146	4.28	138
Leu	6.1	7.94	130	8.25	135	7.81	128
Lys	4.8	2.54	53	2.14	45	1.74	36
Met+Cys	2.4	2.86	119	2.87	120	2.72	113
Phe+Tyr	4.1	9.13	223	12.72	310	11.76	287
Thr	2.5	4.19	168	3.36	134	2.47	99
Trp	0.66	1.34	203	1.67	253	1.76	267
Val	4.0	4.18	105	5.59	140	5.04	126
His	1.6	1.71	107	2.59	162	2.43	152
Total EAA		37.79		43.71		40.02	
CS			53		45		36
PER			2.88		2.94		2.79

*) g/100 g protein. **) FAO [2007]. CS: Chemical score; PER: Protein efficiency ratio.

TABLE 5. Protein evaluation of whole (F-1000) and brown (F-920) ginger cakes by chemical indexes.

Essential amino acids	Requirements for 3–10 years old children **	Ginger cake F-1000*	% Amino acid ginger cake F-1000 /requirements	Ginger cake F-920*	% Amino acid ginger cake F-920 / requirements
Ile	3.1	2.32	75	2.43	78
Leu	6.1	7.30	120	6.60	108
Lys	4.8	1.20	25	1.48	31
Met+Cys	2.4	1.96	82	1.73	72
Phe+Tyr	4.1	6.23	152	5.81	142
Thr	2.5	2.80	112	2.88	115
Trp	0.66	0.94	142	1.01	153
Val	4.0	3.57	98	2.97	74
His	1.6	1.66	104	1.51	94
Total EAA		27.98		26.43	
CS			25		31
PER			2.69		2.36

*) g/100 g protein. **) FAO [2007]. CS: Chemical score; PER: Protein efficiency ratio.

FRESH project from the European Union. E. P. is indebted to a JAE-postdoctoral grant funded by CSIC and FSE-EU.

REFERENCES

1. Adams J.F., Engstrom A., Dietary intake of whole grain *vs.* recommendations. Cereal Foods World, 2000, 45, 75–78.
2. Alsmeyer B.J., Cunningham A.E., Happich M.L., Equations predict PER from amino acid analysis. Food Technol., 1974, 28, 34–40.
3. Andlauer W., Furst P., Does cereal reduce the risk of cancer?. Cereal Foods World, 1999, 44, 76–78.
4. AOAC. Official Methods of Analysis (15th edn). *In*: Association of Official Analytical Chemists, 2000. Washington, DC.
5. Brennan C.S., Cleary L.J., The potential use of cereal (1→3,1→4)-β-D-glucans as functional food ingredients. J. Cereal Sci., 2005, 42, 1–13.
6. Bushuk W., Rye: Production, chemistry, and technology (2nd ed.), Amer. Assn. Cer. Chem., St. Paul, Minnesota. 2001.
7. Charissou A., Ait-Ameur L., Birlouez-Aragon I., Kinetics of formation of three indicators of the Maillard reaction in model cookies: Influence of baking temperature and type of sugar model cookies: Influence of baking temperature and type of sugar. J. Agric. Food Chem., 2007, 55, 4532–4539.
8. Capuano E., Garofalo G., Napolitano A., Zielinski H., Fogliano V., Rye flour extraction rate affects Maillard reaction development, antioxidant activity, and acrylamide formation in bread crisps. Cereal Chem., 2010, 87, 131–136.
9. FAO. Protein and amino acid requirements in human nutrition. Report of Joint WHO/FAO/UNU Expert consultation. WHO Technical Report Series 935, 2007.
10. Horszwald A., Morales F.J., Del Castillo M.D., Zieliński H., Evaluation of antioxidant capacity and formation of processing contaminants during rye bread making. J. Food Nutr. Res., 2010, 49, 149–159.
11. Horszwald A., Troszyńska A., Del Castillo M.D., Zielinski H., Protein profile and sensorial properties of rye breads. Eur. Food Res. Technol., 2009, 229, 875–886.
12. Martínez-Villaluenga C., Gulewicz P., Frias J., Gulewicz K., Vidal-Valverde C., Assessment of protein fraction of three varieties of *Pisum sativum* L. Effect of germination. Eur. Food Res. Technol., 2008, 226, 1465–1478.
13. Michalska A., Ceglińska A., Amarowicz R., Piskuła M.K., Szawara-Nowak D., Zieliński H., The antioxidant contents and antioxidative properties of traditional rye breads. J. Agric. Food Chem., 2007, 55, 734–740.
14. Michalska A., Miryam Amigo-Benavent M., Zielinski H., Del Castillo M.D., Effect of bread making on the formation of Mailar reaction products contributing to the overall antioxidant activity of rye bread. J. Cereal Sci., 2008, 48, 123–132.
15. Mustafa A., Aman P., Andersson R., Kamal-Eldin A., Analysis of free amino acids in cereal products. Food Chem., 2007, 105, 317–324.
16. Nyström L., Lampi A.M., Andersson A.A.M., Kamal-Eldin A., Gebruers K., Courtin C.M., Delcour J.A., Li L., Ward J.L., Fras, A., Boros D., Rakszegi M., Bedo Z., Shewry P.R., Piironen V., Phytochemicals and dietary fiber components in rye varieties in the HEALTHGRAIN diversity screen. J. Agric. Food Chem., 2008, 56, 9758–9766.
17. Pellett P.L., Young V.R., Nutritional Evaluation of Proteins Foods. The United Nations University, 1980.
18. Piekut M., Consumption of bakery products in Polish households. Przegl. Piek. Cuk., 2008, 7, 6–18 (in Polish).
19. Zieliński H., Amigo-Benavent M., Del Castillo M.D., Horszwald A., Zielińska D., Formulation and baking process affect Maillard reaction development and antioxidant capacity of ginger cakes. J. Food Nutr. Res., 2010, 49, 140–148.
20. Zieliński H., Michalska A., Ceglińska A., Lamparski G., Antioxidant properties and sensory quality of traditional rye bread as affected by the incorporation of flour with different extraction rates in the formulation. Eur. Food Res. Technol., 2008, 226, 671–680.
21. Zieliński H., Ciesarova Z., Troszyńska A., Ceglińska A., Zielińska D., Amarowicz R., Przygodzka M., Kukurova K., Antioxidant properties, acrylamide content and sensory quality of ginger cakes with different formulations. Pol. J. Food Nutr. Sci., 2012, 61, 41–50.

Submitted: 17 July 2012. Revised: 10 October 2012. Accepted: 8 November 2012. Published on-line: 15 February 2013.