ENERGY AND NUTRIENT COMPOSITION OF SOUTH AFRICAN WHEAT, WHEAT FLOUR AND BREAD

Technical Report to the Winter Cereal Trust of South Africa

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EXECUTIVE SUMMARY

Aim of the study

The aim of this project was to generate new information on the energy content and nutrient composition of South African wheat, white bread flour and bread.

Methodology

The Southern African Grain Laboratory (SAGL) receives wheat samples annually from the different wheat producing areas in South Africa, to conduct the National Wheat Crop Quality Survey. Representative samples of wheat received by the SAGL from the three major wheat production areas, Western Province (WP), Free State (FS) and Orange River (OR), for the 2005/2006 harvest period, were used. These samples were cleaned on the Dockage tester before it was divided into individual and composite samples. To determine the energy and nutrient composition of whole wheat, samples were milled on the Falling Number laboratory mill. To obtain white bread flour samples, wheat was milled on a Bühler MLU 202 laboratory mill. Brown bread flour samples were obtained by mixing selected bran (12%) back into the white bread flour (88%). Sub-samples were fortified according to national fortification guidelines. Homogeneity tests were conducted on all whole wheat, selected bran, as well as unfortified and fortified white and brown bread flour samples. Bread flour prepared at the SAGL was used to bake bread according to a standardised method. To determine any difference in the flour obtained from the SAGL Bühler laboratory mill and those milled at an industrial mill (Sasko mill at Malmesbury), samples of South African white bread flour milled at both sites (from the same wheat) were compared. Samples were analysed for their macro- and micronutrient content by the SAGL. All the minerals (calcium, iron, potassium, sodium, zinc, manganese, copper, phosphorous, magnesium, chromium and selenium) were analysed by the Agricultural Research Council: Institute for Soil, Climate and Water. The Agricultural Research Council: Irene Analytical Services conducted the vitamin E analysis and the South African Bureau of Standards conducted the analyses for the individual sugars (DP1-DP15), biotin and pantothenic acid. The results were summarised by the laboratories and values were reported as unit per 100 gram edible food. The analyses for all nutrients were conducted once. Results obtained from the laboratories were summarised for this technical report.

Results

The energy content of the white bread flour samples analysed varied between 1468 kJ and 1474 kJ. The protein content of whole wheat (raw) from the Free State (13.4 g/100 g) was higher than that from the Western Province (11.1 g/100 g) or from the Orange River (11.0 g/100 g). The protein content of the individual samples of unfortified white bread flour prepared from the wheat from WP, FS and OR regions, was 10.4 g, 12.5 g and 10.2 g per 100 g respectively, while for the fortified samples the values were 10.3 g, 12.5 g and 10.1 g respectively. Results showed that the available carbohydrate content (calculated) for whole wheat (raw) ranged from 59.5 g to 61.5 g per 100 g for the regional samples, while it was 59.9 g per 100 g for the composite sample. The values for total fat content of the composite whole wheat and bran samples were 1.8 g and 5.1 g per 100 g respectively. The composite sample of bran (selected) had a dietary fibre content of 36.9 g per 100 g.

There were good agreement between the values reported for protein, carbohydrate and fat content of the different wheat flour samples milled at the SAGL and those milled at SASKO.

The iron content of unfortified white and brown bread was 1.7 mg and 1.9 mg respectively. In fortified white bread and brown bread, the iron (3.6 mg; 4.1 mg) and zinc (2.15 mg; 4.49 mg) content were markedly higher than in the unfortified bread.

Conclusion

This study provided for the first time comprehensive information on the nutrient composition of South African wheat and white bread flour milled from it. In addition, white and brown bread baked from the South African wheat flour were analysed and provided valuable nutrient information. Values on the nutrient composition of unfortified white bread flour, fortified white bread flour and bread baked from these flours could serve as guidelines for the food industry with reference to the national food fortification programme. The new data generated will now be included in the South African Food Composition Database.

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ABBREVIATIONS

ARC-IRENE	**Agricultural Research Council – Irene Analytical Services**
ARC-ISCW	**Agricultural Research Council – Institute for Soil, Climate and Water**
C	**Composite**
DP	**Degree of polymerization**
FCT	**Food Composition Tables**
FS	**Free State**
MRC	**Medical Research Council**
NIRU	**Nutritional Intervention Research Unit**
OR	**Orange River**
SABS	**South African Bureau of Standards**
SAFOODS	**South African Food Composition Data System**
SAGL	**Southern African Grain Laboratory**
SANAS	**South African National Accreditation System**
SASKO	**Suid-Afrikaanse Sentrale Koöperatiewe Graanmaatskappy**
WP	**Western Province**

1. INTRODUCTION

1.1 Background information

The South African Food Composition Data System (SAFOODS) is widely used in printed format and as part of a software program by South Africans. Although the aim is to mainly include foods with nutrient values of South African origin in the database, this is not always possible as a result of cost constraints that impact on the generation of South African data. There is an urgent need to increase the percentage of South African values in the database and the goal is to concentrate especially on those foods that form part of the staple foods of South Africans.

Presently no nutrient information exists for white bread flour in SAFOODS, but only for wheat flour. The nutrient information on wheat flour in SAFOODS is not of South African origin, but it was borrowed from the United States Department of Agriculture (USDA), (Drake *et al*., 1989) and the British database (Holland *et al.*, 1988). The information on the energy (kilojoules), protein, carbohydrate, fatty acid, vitamin and mineral content of wheat and wheat products may thus differ from values of South African origin. Baseline values on the nutrient composition of white bread flour are required especially because of the legislation on the fortification of the staple foods in South Africa. The aim of the Nutritional Intervention Research Unit (NIRU) was therefore to update the information on the nutrient content of wheat and wheat products in order to meet the needs of the users of SAFOODS.

Products from the database, e.g. books and software programs, are for use by the food industry, nutrition fraternity and the general public. Today the food industry is one of the main users of the food composition tables, and the tables will become even more important in future as a result of the requirements for product labelling and because of food fortification.

2. AIM OF THE STUDY

The aim of this study was to determine the nutrient content of South African wheat, selected bran, white bread flour, brown bread flour and white and brown bread, by chemical analyses.

3. METHODOLOGY

3.1 Sampling of wheat

As a result of the high import of wheat into South Africa it was decided to collaborate with the Southern African Grain Laboratory (SAGL) to obtain representative samples of South African wheat. Representative samples of wheat are received annually by the SAGL from the major wheat producing regions, Western Province (WP), Free State (FS) and Orange River (OR), to determine the wheat crop quality as part of their annual survey. Representative wheat samples per class and grade, per silo, are received from all over South Africa. A total of 480 (5 kg) samples are received annually by the SAGL. A specific procedure is used to obtain the 5 kg representative sample which is sent to the SAGL. During intake of wheat at the silos, a representative sample is drawn for grading purposes. About 500 g of these samples are thrown into specific bins per class and grade. After these bins are filled, it is divided to get a homogeneous sample of 5 kg per class and grade. In 2006, 182 x 5 kg of these crop samples were received from the WP, 137 x 5 kg from the FS and 111 x 5 kg from the irrigation areas (OR). The balance of the samples was from other smaller production regions. In this study the samples received for the 2005/2006 harvest were used.

Permission was obtained from the Grain Silo Industry to use these wheat samples for analysis of the nutrient composition of wheat, selected bran, white bread flour, brown bread flour, white and brown bread.

The SAGL took 200 g to 300 g of each of the crop samples (the 5 kg samples) to prepare the three composite samples of 30 kg each to represent the three major production areas. These representative samples of wheat were used for determining the nutrient composition of South African wheat and wheat products.

3.2 Wheat and wheat products identified for analysis

The wheat and wheat products identified for analysis are summarised in **Table 1**.

Table 1. Wheat and wheat products identified for analysis

Code for Individual samples	**Name**
WP-WW	WP-whole wheat
FS-WW	FS-whole wheat
OR-WW	OR-whole wheat
WP-SB	WP-selected bran
FS-SB	FS-selected bran
OR-SB	OR-selected bran
WP-UWBF	WP-unfortified white bread flour
FS-UWBF	FS-unfortified white bread flour
OR-UWBF	OR-unfortified white bread flour
WP-FWBF	WP-fortified white bread flour
FS-FWBF	FS-fortified white bread flour
OR-FWBF	OR-fortified white bread flour
Code for Composite samples	
C-WW	Composite-whole wheat
C-SB	Composite-selected bran
C-UWBF	Composite-unfortified white bread flour
C-FWBF	Composite-fortified white bread flour
C-UWB	Composite-unfortified white bread
C-UBB	Composite-unfortified brown bread
C-FWB	Composite-fortified white bread
C-FBB	Composite-fortified brown bread
Code for SASKO and SASKO-SAGL samples	
SAS-UWBF	SASKO-unfortified white bread flour
SAGL-UWBF	SASKO-SAGL-unfortified white bread flour
SAS-UBBF	SASKO-unfortified brown bread flour
SAGL-UBBF	SASKO-SAGL-unfortified brown bread flour

WP = Western Province; FS = Free State; OR = Orange River
Composite = Sample formed by mixing WP, FS and OR together
C = Composite
SASKO = Suid-Afrikaanse Sentrale Koöperatiewe Graanmaatskappy
SAGL = Southern African Grain Laboratory

3.3 Preparation of the wheat samples at the Southern African Grain Laboratory

3.3.1 Cleaning of wheat

Before the 30 kg samples of wheat were divided for analysis purposes, unmillable products such as weed, dirt, chaff and possibly stones were removed by using the Dockage tester (WSS 017-SOP). Each 30 kg sample was divided three times using the prescribed sample divider for wheat ("Boerner sample divider"). Each 30 kg sample was then tested for homogeneity.

3.3.2 Testing for homogeneity

A test for homogeneity was done on each 30 kg of wheat sample (SOP No. WWS 007). Five small samples of wheat were taken from different areas of the representative samples and tested for protein and moisture content. The five results had to be within the standard deviation for the specific analysis to be considered homogeneous.

3.4 Sub-division of wheat samples

A 2 kg and a 1 kg wheat sample were taken from each of the homogeneous 30 kg regional samples. The 2 kg wheat sample from each region represented the sample on which analyses were performed to provide nutrient data on whole wheat for each individual region. The 1 kg wheat samples from each of the three regions were combined to provide a 3 kg composite wheat sample for analysis. The remaining 27 kg of wheat from each region was used for the preparation of white bread flour.

3.5 Preparation of whole wheat samples

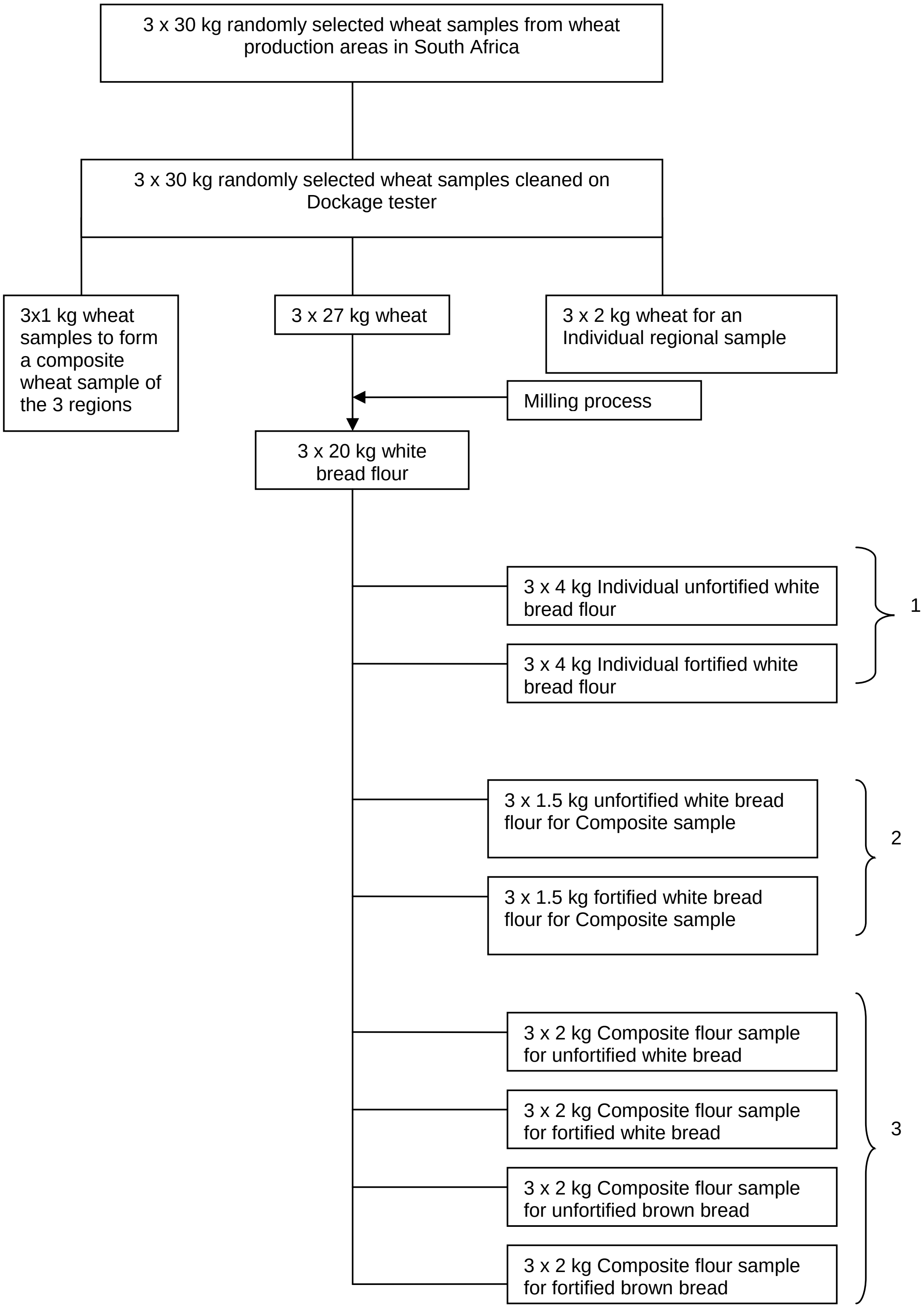
The 2 kg wheat samples taken from each regional sample were milled on a Falling Number mill to obtain a whole wheat product for analysis. The other 1 kg wheat sample of each region were combined together, divided homogeneously and then milled on the Falling Number mill to obtain a combined whole wheat sample. After milling each sample was tested again for homogeneity as described in 3.3.2.

3.6 Preparation of white bread flour

The remaining 27 kg of wheat from each of the three regional samples was milled (IA/BA 011 & 012). Each sample was milled on a Bühler MLU 202 laboratory mill to obtain white bread flour samples. The same Bühler mill was used to mill each of the regional samples to avoid possible variation during the milling process. For each of the 27 kg regional wheat samples milled, about 20 kg of white bread flour was obtained. These white bread flour samples were then tested for homogeneity using the same procedure as described in 3.3.2.

The 20 kg regional white bread flour samples were used to prepare individual and composite samples. **Figure 1** illustrates how the 20 kg white bread flour sample from each region was divided.

Figure 1. Overview of the stages involved in the production and division of the 20 kg white bread flour samples



1. Individual unfortified and fortified white bread flour samples for analysis for each region namely WP, FS and OR.
2. Unfortified and fortified white bread flour samples to make up Composite flour samples representing WP, FS and OR.
3. Unfortified and fortified white bread and brown bread flour to make up Composite flour samples representing WP, FS and OR for baking white and brown bread respectively.

3.6.1 Individual samples of white bread flour

White bread flour samples from each of the different production areas (individual samples) were prepared (See Figure 1). Two batches of white bread flour of 4 kg each were obtained from each of the 20 kg regional white bread flour samples. One 4 kg sample represented unfortified white bread flour and one 4 kg sample was fortified to represent the fortified white bread flour. These 4 kg samples represented the individual samples analysed for the nutrient composition of white bread flour from the individual regions. See 3.7.1 for the fortification of white bread flour.

3.6.2 Composite samples for white bread flour

Two samples of white bread flour, 1.5 kg each, were sampled from each of the three regions, WP, FS and OR (See Figure 1). To make up the composite samples of unfortified and fortified white bread flour, the procedure described below was followed:
(a) Three 1.5 kg samples, one from each of the three regions, were mixed to form a 4.5 kg composite sample of unfortified white bread flour. The mixture was tested for homogeneity as described in 3.3.2.

(b) Three 1.5 kg samples, one from each of the three regions, were mixed to form a 4.5 kg composite sample of white bread flour to be fortified as described in 3.7.1. The mixture was tested for homogeneity according to the methodology described in 3.3.2, but the sample was tested for the water-soluble vitamins, B_1, B_3 and B_6.

3.7 Composite samples for baking bread

Four batches of 2 kg white bread flour each were taken from each of the 20 kg regional flour samples to prepare a composite sample for the baking of bread (See Figure 1). The 2 kg samples were combined to form four (6 kg each) composite samples of white bread flour for baking the following types of bread:
(a) unfortified white bread;
(b) fortified white bread (see 3.7.1 for information on the fortification of white bread flour);
(c) unfortified brown bread (See 3.7.3 for the preparation of brown bread flour);
(d) fortified brown bread (See 3.7.3 for the preparation of brown bread flour and 3.7.1 for the fortification of white bread flour).

3.7.1 Fortification of white bread flour

To fortify the flour samples, a micronutrient premix was obtained from a registered manufacturer, DSM Nutritional Products. White bread flour was fortified using a micronutrient pre-mix containing vitamin A, thiamin, riboflavin, niacin, vitamin $B_{6,}$ folic acid, iron and zinc. To avoid nutrient loss in the micronutrient premix, it was always stored and used while in a dark room. The micronutrient premix was tested for homogeneity by analysing the water-soluble vitamins, B_1, B_3 and B_6.

3.7.2 Collecting bran samples

The wheat samples were milled with a laboratory mill (Bühler MLU 202) to separate the different layers of the whole wheat kernel (See 3.6). During the milling process the bran is separated from the endosperm and the end result is bran and flour.

The following samples of bran were collected:
(1) One sample of selected bran of 1.2 kg each was sampled from each of the regional samples. Selected bran is obtained by putting the bran, obtained through the milling process on the Bühler mill, through the bran finisher. Thereafter the bran is sieved through a 2 mm sieve and thereafter a 500 µm sieve. The bran remaining on top of the 500 µm sieve is then used. The samples were tested for homogeneity as described in 3.3.2. These samples were analysed for the nutrient content of the individual samples.

(2) One sample of 500 g selected bran from each of the regional samples was collected and mixed to prepare a composite bran sample to represent all three regions. The composite bran sample was tested for homogeneity as described in 3.3.2.

3.7.3 Preparation of brown bread flour

Two of the 6 kg white bread flour composite samples made up as described in 3.7 were used to prepare the brown bread flour. Twelve percent of selected bran (as specified in the Foodstuffs, Cosmetics and Disinfectants Act, R2003/ 1972) was added to 88 % white bread flour to form brown bread flour.

One of the 6 kg samples of brown bread flour was tested for homogeneity as described in 3.3.2 and this flour was used for baking the unfortified brown bread. The other sample of brown bread flour was fortified as described in 3.7.1 for baking fortified brown bread. To test for homogeneity the same procedure as described in 3.3.2 was followed, except that the sample was tested for the water-soluble vitamins B_1, B_3 and B_6.

3.8 Milling of wheat samples obtained from Malmesbury mill

To determine any possible differences between wheat flour obtained from the same wheat milled at the SAGL (Bühler MLU 202 laboratory mill) and by an industrial mill (Malmesbury Sasko mill), the flour obtained by the two different mills were analysed for macronutrient and amino acid content. The aim was to compare the results obtained from these two samples in order to identify possible differences in nutrient composition.

To prepare SASKO and SASKO-SAGL brown bread flour respectively, the same procedure as described above for unfortified flour (see 3.7.3) was followed.

3.9 Baking of bread

Bread flour prepared at the SAGL was used to bake bread according to a standardised method. Baking tests were conducted on the unfortified and fortified 6 kg composite bread samples. A baking method based on the Chorleywood baking test was conducted on the bread (Lab. No. IAM 018). This process is a method which provides a basic baking test for evaluating bread wheat flour quality. The SAGL uses this method for laboratory assessment of bread quality. The bread loaves were scored on a score sheet and the following characteristics were evaluated:

a) symmetry of form
b) top crust
c) break and shred
d) evenness of bake
e) grain
f) texture
g) crumb colour

h) variable colour
i) weight and volume.

Baking tests were also conducted on the white bread flour and brown bread flour obtained from the Malmesbury mill, however, nutritional analysis was not conducted on this bread.

4. ANALYSIS OF SAMPLES

4.1 Selection criteria for laboratories

The criteria used for selection of the laboratories for analysis were, *inter alia* (a) cost of analysis; (b) methods which are South African National Accreditation System (SANAS) accredited and (c) location of laboratories.

4.2 Distribution of samples

The SAGL delivered all the samples to the relevant laboratories for the specific analyses. The samples were individually wrapped in plastic bags, then in paper bags and then placed in brown boxes and firmly sealed. These samples were packaged carefully to avoid moisture loss or absorption during the transportation process and whilst in storage at the various laboratories. After all the samples were delivered at the laboratories, follow-up phone calls were conducted by a researcher from NIRU (Natasha Danster (ND)) to ensure all samples had been received. All the samples were stored under proper storage conditions whilst waiting to be analysed.

To ensure that satisfactory progress was made with the analysis of the data, regular contact with all the laboratories was maintained by a researcher (ND) from NIRU via e-mails and telephone calls. The relevant laboratory managers or persons responsible for the analysis were contacted.

4.3 Nutrient analyses

The majority of the analyses were done by the SAGL. The Agricultural Research Council – Institute for Soil, Climate and Water (ARC-ISCW) was responsible for analysing the minerals. The Agricultural Research Council - Irene Analytical Services (ARC-IRENE) conducted only the vitamin E analysis. The South African Bureau of Standards (SABS) analysed the wheat samples for individual sugars, biotin and pantothenic acid content.
The nutrients analysed, methods used for analyses and the responsible laboratories are summarised in **Tables 2 and 3**.

Table 2. Methods used for energy and macronutrient analyses

Macronutrient	Method used	Laboratory	SANAS accredited
Moisture	Oven drying at 130°C	SAGL[1]	Yes
Ash	Ashing done at 700°C	SAGL	Yes
Energy	Calculated[2]	SAGL	Not applicable
Protein	Dumas method	SAGL	Yes
Total nitrogen	Dumas method	SAGL	Yes
Amino acids	HPLC[3]	SAGL	No
Fat	Soxhlet extraction	SAGL	Yes
Carbohydrate[4]	Calculated	SAGL	Not applicable
Starch	Centrifugation	SAGL	No
Total dietary fibre	In-house (AOAC Method 985.29)	SAGL	Yes
Total sugars	HPLC	SABS[5]	No

[1] SAGL = Southern African Grain Laboratory
[2] Energy was calculated using 17 kJ/g, 17 kJ/g and 37 kJ/g for protein, available carbohydrates plus fibre and fat respectively.
[3] HPLC = High Performance Liquid Chromatography
[4] The available CHO in gram by difference content was calculated by subtracting the percentage values of water (moisture), protein, fat and total dietary fibre from 100. Total CHO represents available carbohydrate plus dietary fibre.
[5] SABS = South African Bureau of Standards

Table 3. Methods used for micronutrient analyses

Micronutrient	Method used	Laboratory	SANAS accredited
Copper	ICP-MS[1]	ARC-ISCW[2]	No
Iron	ICP-MS	ARC-ISCW	No
Manganese	ICP-MS	ARC-ISCW	No
Potassium	ICP-OES[3]	ARC-ISCW	No
Sodium	ICP-OES	ARC-ISCW	No
Zinc	ICP-MS	ARC-ISCW	No
Calcium	ICP-OES	ARC-ISCW	No
Magnesium	ICP-OES	ARC-ISCW	No
Selenium	ICP-MS	ARC-ISCW	No
Phosphorous	ICP-OES	ARC-ISCW	No
Chromium	ICP-MS	ARC-ISCW	No
Vitamin A	HPLC[4]	SAGL[5]	Yes (fortified product)
Thiamin	HPLC	SAGL	Yes (fortified product)
Riboflavin	HPLC	SAGL	Yes (fortified product)
Niacin	HPLC	SAGL	Yes (fortified product)
Vitamin B_6	HPLC	SAGL	Yes (fortified product)
Folic acid	HPLC	SAGL	Yes (fortified product)
Pantothenic acid	Microbiological assays	SABS[6]	No
Biotin	Microbiological assays	SABS	No
Vitamin E	HPLC	ARC-IRENE[7]	Yes

[1] ICP-MS = Inductive Coupled Plasma-Mass Spectometry
[2] ARC-ISCW = Agricultural Research Council-Institute for Soil, Climate and Water
[3] ICP-OES = Inductive Coupled Plasma-Optical Emission Spectometry
[4] HPLC = High Performance Liquid Chromatography
[5] SAGL = Southern African Grain Laboratory
[6] SABS = South African Bureau of Standards
[7] ARC-IRENE = Agricultural Research Council-Irene Analytical Services

5. RESULTS

Results on the nutrient composition of the wheat and wheat products were provided by the different laboratories to NIRU in four separate reports. In this technical report results from these reports are summarised. All values were reported as unit per 100 gram. The analyses for all nutrients were conducted once.

The SAGL reported the results on the energy and macronutrient content (**Table 4**) as well as the micronutrient content (**Table 5**) of the wheat and wheat products. Biotin and pantothenic acid values were provided by the SABS and vitamin E by the ARC-IRENE (**Table 5**). The ARC-ISCW reported on all the minerals (**Table 6**). The SABS reported on the individual sugars (**Table 7**).

In **Table 4** results are shown for moisture, energy (calculated), total nitrogen, protein, total fat, available carbohydrate (by difference), total dietary fibre, starch and ash.

The moisture content was standardised at 14% for wheat flour and at 39% for bread. The moisture of all the samples was done by oven method by the SAGL.

Energy content of the wheat flour varied between 1 466 kJ and 1 474 kJ (**Table 4**).

The protein content of wheat from the Free State (13.4 g/100 g) was higher than that from the Western Province (11.1 g/100 g) or from the Orange River (11.0 g/100 g). This difference was also reflected in the protein content of the wheat flour (**Table 4**). Usually wheat flour average 0.8 % less protein than the whole wheat (personal communications: C Buitendag, SAGL, 2007). The mean values calculated from the individual unfortified (11.0 g/100 g) and fortified (11.0 g/100 g) white bread flour samples compare well with the values of the applicable composite samples, 11.2 g/100 g (unfortified) and 10.8 g/100 g (fortified), respectively (**Table 4**).

In whole wheat, the available carbohydrate content ranged from 59.5 g to 61.5 g per 100 g for the regional samples. The available carbohydrate content for the composite whole wheat sample was 59.9 g per 100 g.

The available carbohydrate content of unfortified white bread flour milled at the SAGL and the unfortified white bread flour milled at SASKO were the same. For the unfortified white bread flour composite sample, the available carbohydrate content was 71.1 g per 100 g.

In white bread, the available carbohydrate content was approximately 45 g per 100 g while it was approximately 43 g per 100 g for the brown bread (**Table 4**).

The fibre content of selected bran ranged between 34.6 g and 37.7 g per 100 g for the different regions and for the composite sample it was 36.9 g per 100 g (**Table 4**).

Analyses of the vitamin content of whole wheat, bran, white bread flour and bread are given in **Table 5**. The following vitamins were determined: vitamin A, thiamin, riboflavin, niacin, vitamin B_6, folic acid, pantothenic acid, biotin and vitamin E. Due to financial constraints not all the vitamins were analysed, however, some vitamins were omitted purposefully. As vitamin C is found mainly in fruits and vegetables and vitamin B_{12} in animal products (Wolmarans *et al.*, 1992) these were omitted for analysis. The riboflavin content of the regional unfortified white bread flour samples, i.e. WP, FS and OR, was 0.06 mg, 0.07 mg and 0.02 mg per 100 g respectively. As expected, values were higher for the regional fortified white bread flour samples, 0.17 g, 0.16 g and 0.15 g per 100 g for the WP, FS and OR regions, respectively. The riboflavin content of the composite fortified white bread flour sample was 0.16 mg per 100 g, which compares well with the mean (0.16 mg/100 g), calculated from the values of the individual regional samples. The folic acid values in unfortified white and brown bread were 20 µg and 80 µg per 100 g respectively.

Results on the mineral composition of whole wheat, bran, white bread flour and bread are given in **Table 6**. Samples were analysed for the following minerals: calcium, iron, potassium, sodium, zinc, manganese, copper, phosphorous, magnesium, chromium and selenium. The iron and zinc content of the fortified white bread flour and bread samples were markedly higher than in the unfortified samples. This could be expected as the samples were fortified with iron and zinc.

The samples were also analysed for 15 individual sugars, DP1-DP15 (**Table 7**). The carbohydrates are classified according to the degree of polymerization (DP), DP1-DP15. Results showed that in most instances these nutrients were not detected in the samples. DP-1 was found in selected bran, but not in the other wheat or wheat flour samples nor in the bread samples. DP-2 and DP-3 were detected in wheat, bran, wheat flour and in bread, but it was not a consistent finding. No values were detected or determined for DP-4 to DP-15.

In **Table 8** the amino acid composition of whole wheat, bran, white bread flour and bread are given. To save costs, amino acids were only determined in whole wheat, bran, unfortified flour and unfortified white and brown bread, and not in fortified flour and bread.

6. DISCUSSION

For this project, whole wheat, selected bran, white bread flour, brown bread flour and bread samples were analysed.

In the 1991 edition of the MRC FCT (Langenhoven *et al*., 1991), no values are available for whole wheat or white bread flour.

The bran layer is rich in protein, cellulose, hemicellulose and ash (American Institute of Baking, 1990). This is in line with the study results as the protein and ash values per 100 g are highest in bran compared to that of the whole wheat and flour samples. The values for bran in the 1991 MRC FCT are for crude bran. The fibre content reported for crude bran was 42.4 g per 100 g edible portion. The values for crude bran in the 1991 MRC FCT were borrowed from the USDA (Drake *et al*., 1989). The AOAC method was used to determine the total dietary fibre content of wheat bran (crude) in the 1991 MRC FCT. In this study, the AOAC Method 985.29, 1998, was used to determine total dietary fibre. Small changes was made to this method namely: 1) using 150 mL petroleum ether to defat the sample instead of using three times 25 mL per portion/g sample; 2) not adding exactly 10 mL of NaOH and HCL but adding until the correct pH is obtained for obtaining more accurate results.

No values exist in the 1991 MRC FCT for unfortified white bread flour and this study provided valuable new information. The energy value (1468 kJ/100 g) for the composite unfortified white bread flour sample compares well with the mean energy content calculated for the three regional samples (1470 kJ/100 g). The energy content of the unfortified white bread flour sample (1472 kJ/100 g) milled industrially, was approximately the same as the energy content of the unfortified white bread flour sample (1474 kJ/100 g) milled at the SAGL. There were good agreement between the values reported for protein, carbohydrate and fat content of the different wheat flour samples analysed at the SAGL and those analysed at SASKO.

Analysis of the vitamins (**Table 5**) showed that for the regional fortified white bread flour samples, the vitamin A, thiamin, riboflavin, niacin, folic acid and vitamin B_6 values were much higher than for the unfortified samples. The same applies to the fortified composite white bread flour sample which also illustrated raised values for the above-mentioned vitamins. This confirmed that the samples were fortified. According to the Foodstuffs, Cosmetics and Disinfectants Acts, Act no. 54 of 1972, the micronutrients should be reported at a 14% moisture basis for fortified white bread flour and at a 39% moisture basis for bread. Fortification standards for the micronutrients should be met and must be in accordance with the net values as mentioned in Annexure VI, Table 5 (a) of the Act. The values for vitamin A (34%), thiamin (38%), niacin (90%), vitamin B_6 (82%) and folate (121%) in the composite fortified white bread flour, sample were all higher than the legislation standards. The values for riboflavin (22%), iron (33%) and zinc (29%) were lower than the values specified in legislation. As expected the zinc and iron content of fortified white bread flour was higher than in the unfortified samples (**Table 6**). The values for niacin in this study represent nicotinic acid plus nicotinamide. An in-house method was used by the SAGL for the determination of niacin.

In this study the unfortified and fortified products were analysed for folic acid content (**Table 5**). To determine this, the SAGL used an HPLC method. According to Greenfield and Southgate (2003) folic acid does not occur naturally in foods, but is widely used in food fortification. Gebhardt *et al*., 2006, stated that folic acid occurs rarely in foods and is the form used for the fortification of foods. The methodology used in this study only determined the folic acid content of the samples and not also the food folate content. In order to calculate the Dietary Folate Equivalents for folic acid, the micrograms of folic acid present, as well as the micrograms of food folate present in a food should be known (Gebhardt and Holden, 2006). The ideal analytical nutritional procedure for food folates in wheat should therefore be able to distinguish between the different folate derivatives (Greenfield and Southgate, 2003). It is therefore recommended that in future a microbiological or a HPLC method that can distinguish between the different folate derivatives when determining food folate in wheat is used.

A very small variation in the energy content of the four breads analysed was observed (**Table 4**). In the 1991 MRC FCT, the energy content of unfortified white and brown bread was 1000 kJ/100 g and 930 kJ/100 g, respectively (Langenhoven *et al*., 1991). The new energy values reported for bread are slightly higher than the values reported in the 1991 MRC FCT (**Table 4**).

In this study as well as in the 1991 MRC FCT, the carbohydrate value represents available carbohydrate. Available carbohydrate can be defined as the sum of free sugars (glucose, fructose, sucrose, lactose and maltose), starch, dextrins and glycogen (Greenfield and Southgate, 2003). The value in the 1991 MRC FCT and in this study was calculated by difference. Available carbohydrate by difference is calculated by subtracting the percentage of water, protein, fat, ash and total dietary fibre from 100 (Greenfield and Southgate, 2003). In the 1991 MRC FCT the available carbohydrate content of white bread (49.3 g) and brown bread (44.1 g) was slightly higher than that of the unfortified white bread (45.2 g) and brown bread (42.7 g) analysed in this study. In this project, the individual sugars and starch were also analysed.

Values reported in unfortified white and brown bread for iron were 1.2 mg and 1.5 mg per 100 g, respectively, in the 1991 MRC FCT (Langenhoven *et al*., 1991). In this study the iron content for unfortified white and brown bread was 1.7 mg and 1.9 mg respectively. For the fortified white and brown bread, the iron (3.6 mg; 4.1 mg) and zinc (2.15 mg; 4.49 mg) content were markedly higher than the unfortified bread.

Eighteen amino acids were included in the analyses, of which eight were essential amino acids (histidine, isoleucine, lysine, leucine, phenylalanine, threonine, tyrosine and valine). The analysis indicates that wheat, bran, wheat flour and bread are all sources of essential amino acids. This study has provided updated amino acid information for the MRC FCT, as the previous values were outdated (Kruger *et al*., 1991).

7. CONCLUSION

The aim of this study was to generate new information on the energy and nutrient composition of South African wheat and wheat products.

For the first time, nutrient values are available for South African wheat, bran, white and brown bread flour. Values are also available for unfortified and fortified white and brown bread, baked from South African bread flour. This information could be used as a guideline by the food industry for the fortification of white bread flour and bread.

Involving the food industry in this study proved to be of major importance. Information on the import of wheat into the country and how to ensure that South African wheat was sampled for this project was provided by the food industry. The collaboration between NIRU and the SAGL ensured that representative samples of South African wheat could be used for the analysis of the nutrient composition of wheat and wheat products. The SAGL is the reference laboratory for grain quality analysis in Southern Africa. Their services include national projects like the annual wheat crop quality survey, where certain procedures are already in place to obtain representative samples for such studies. Collaboration with the SAGL when studies are undertaken to analyse the nutrient composition of grain products, is therefore recommended.

The study to generate new information on the energy content and nutrient composition of South African wheat and wheat products should be seen as part of an ongoing process to generate new information on the nutrient composition of South African foods.

8. AVAILABILITY OF THE DATA

In addition to this report the data will be made available as follows:

a. Inclusion in FoodFinder3 software program
b. Added to the food composition data available on the www.sahealthinfo.co.za website
c. Presentation of the results at national/international congresses
d. Publication of the data in a scientific journal
e. This publication will be available from the Medical Research Council. Requests should be addressed to:
   Nutritional Intervention Research Unit
   Medical Research Council
   PO Box 19070
   Tygerberg
   7505

9. REFERENCES

American Institute of Baking. (1990). *The Science of Baking*. American Institute of Baking, Manhattan.

Department of Health. (2007). *Foodstuffs, Cosmetics and Disinfectants Act, (no.54 of 1972)*. [On line]. http://www.doh.go.za/docs/regulations/2003/ffortification.html

Drake, D.L., Gebhardt, S.E. & Matthews, R.H. (1989). *Composition of Foods: Cereal Grains and Pasta*. Agricultural Handbook No 8-20. USDA, Washington.

Gebhardt, S. & Holden, J. (2006). Consequences of changes in the Dietary Reference Intakes for nutrient databases. *Journal of Food Composition and Analysis*, **19**: S91-S95.

Greenfield, H. & Southgate, D.A.T. (2003). *Food Composition Data. Production, Management and Use*. 2nd Edition. Food and Agricultural Organization of the United Nations, Rome.

Holland, B., Unwin, I.D. & Buss, D.H. (1988). *Cereals and Cereal Products. The Third Supplement to McCance & Widdowson's The Composition of Foods (4th Edition)*. Royal Society of Chemistry, Cambridge.

Kruger, M., Langehnoven, M. & Faber, M. (1991). *Fatty Acid and Amino Acid Composition Tables*. Parow: National Research Programme for Nutritional Intervention, Medical Research Council, 1991.

Langenhoven, M.L., Kruger, M., Gouws, E. & Faber, M. *MRC Food Composition Tables*. Third Edition (1991). Parow: National Research Programme for Nutritional Intervention, Medical Research Council, 1991.

Wolmarans, P., Langenhoven, M. & Faber, M. (1992) *Food, Facts and Figures*. Oxford University Press, Cape Town.

10. ABBREVIATIONS USED IN NUTRIENT TABLES
(listed alphabetically)

Macronutrients, minerals and vitamins

A-µgRE	Vitamin A in microgram retinol equivalents
Ash-g	Ash in gram
B6-mg	Vitamin B_6 in milligram
Biot-µg	Biotin in microgram
Ca-mg	Calcium in milligram
CHO-g	Available carbohydrate in gram
Cr-µg	Chromium in microgram
Cu-mg	Copper in milligram
E-mg	Vitamin E in milligram
En-kJ	Energy in kilojoule
Fat-g	Total fat in gram
Fe-mg	Iron in milligram
Fol-µg	Folic acid in microgram
Fruc-g	Fructose in gram
K-mg	Potassium in milligram
Mg-mg	Magnesium in milligram
Mn-µg	Manganese in microgram
Mois-g	Moisture (water) in gram
Na-mg	Sodium in milligram
Niac-mg	Niacin in milligram
P-mg	Phosphorous in milligram
Pant-mg	Pantothenic acid in milligram
Prot-g	Total protein in gram
Ribo-mg	Riboflavin in milligram
Se-µg	Selenium in microgram
Sta-g	Starch in gram
Sucr-g	Sucrose in gram
TFib-g	Total dietary fibre in gram
Thia-mg	Thiamin in milligram
TotN-g	Total nitrogen in gram
Zn-mg	Zinc in milligram

Amino acids

ALA-g	Alanine in gram
ARG-g	Arginine in gram
ASP-g	Aspartic acid in gram
CYS-g	Cystine in gram
GLU-g	Glutamic acid in gram
GLY-g	Glycine in gram
HIS-g	Histidine in gram
ILE-g	Isoleucine in gram
LEU-g	Leucine in gram
LYS-g	Lysine in gram
MET-g	Methionine in gram
PHE-g	Phenylalanine in gram
PRO-g	Proline in gram
SER-g	Serine in gram
THR-g	Threonine in gram
TRP-g	Tryptophane in gram
TYR-g	Tyrosine in gram
VAL-g	Valine in gram

Symbols used in the tables

N/A	Not Applicable
ND	Not Detected
NT	Not Tested

Table 4. MACRONUTRIENTS: Values for wheat, bran, white bread flour, brown bread flour and bread.

Energy and nutrients Unit per 100 g edible food	Mois g	En kJ	TotN g	Prot g	Fat g	CHO g	TFib g	Sta g	Ash g
WHOLE WHEAT, RAW									
WP, whole wheat	14.0	1468	1.94	11.1	1.9	61.2	9.9	57.8	1.9
FS, whole wheat	14.0	1472	2.35	13.4	1.7	59.5	10.0	57.1	1.4
OR, whole wheat	14.0	1467	1.92	11.0	1.6	61.5	10.3	58.1	1.6
Composite, whole wheat	14.0	1469	2.09	11.9	1.8	59.9	10.7	58.1	1.7
SELECTED BRAN									
WP, selected bran	14.0	1483	2.55	14.6	5.3	26.5	34.6	17.8	5.0
FS, selected bran	14.0	1487	3.07	17.5	5.0	23.5	35.6	15.5	4.4
OR, selected bran	14.0	1467	2.59	14.8	5.2	22.5	37.7	16.3	5.8
Composite, selected bran	14.0	1482	2.71	15.5	5.1	23.7	36.9	16.1	4.8
WHEAT FLOUR									
WP, unfortified white bread flour	14.0	1473	1.82	10.4	0.9	71.7	2.6	67.2	0.5
WP, fortified white bread flour	14.0	1470	1.81	10.3	0.8	72.7	1.7	69.3	0.5
FS, unfortified white bread flour	14.0	1470	2.18	12.5	0.8	69.5	2.7	66.2	0.5
FS, fortified white bread flour	14.0	1468	2.19	12.5	0.7	70.9	1.4	68.7	0.5
OR, unfortified white bread flour	14.0	1468	1.79	10.2	0.8	72.1	2.3	69.6	0.6
OR, fortified white bread flour	14.0	1468	1.77	10.1	0.8	73.7	0.8	70.4	0.6
Composite, unfortified white bread flour	14.0	1468	1.96	11.2	0.7	71.1	2.5	65.9	0.5
Composite, fortified white bread flour	14.0	1470	1.89	10.8	0.8	71.2	2.7	69.4	0.5
SASKO, unfortified white bread flour	14.0	1472	1.96	11.2	1.2	69.7	3.1	66.4	0.8
SAGL, unfortified white bread flour	14.0	1474	1.86	10.6	1.0	69.7	4.2	67.9	0.5
SASKO, unfortified brown bread flour	14.0	1472	2.00	11.4	1.5	65.4	6.5	62.5	1.2
SAGL, unfortified brown bread flour	14.0	1466	1.94	11.1	1.4	66.3	5.8	63.5	1.4
BREAD									
Unfortified white bread	39.0	1015	1.39	8.7	1.2	45.2	3.2	42.2	2.7
Fortified white bread	39.0	1036	1.41	8.8	1.4	45.9	3.2	42.1	1.7
Unfortified brown bread	39.0	1030	1.44	9.0	1.5	42.7	5.6	38.8	2.2
Fortified brown bread	39.0	1029	1.44	9.0	1.4	43.0	5.5	38.6	2.1

Table 5. VITAMINS: Values for wheat, bran, white bread flour and bread.

Vitamins Unit per 100 g edible food	A µgRE	Thia mg	Ribo mg	Niac mg	B6 mg	Fol µg	Pant mg	Biot µg	E mg
WHOLE WHEAT, RAW									
WP, whole wheat	ND	0.29	0.05	8.7	0.47	310	0.78	6.5	0.76
FS, whole wheat		0.33	0.10	9.5	0.63	380	0.95	7.8	0.98
OR, whole wheat	ND	0.25	0.08	10.1	0.51	190	0.91	5.5	1.10
Composite, whole wheat	0.4	1.11*	0.07	6.1*	0.49*	360	0.91	6.0	1.00
SELECTED BRAN									
WP, selected bran		2.87	0.60	15.4	0.87	910	2.14	29.1	1.83
FS, selected bran	ND	2.75	0.79	14.4	1.51	1220	2.41	23.5	2.16
OR, selected bran	ND	2.44	0.78	12.6	1.37	960	2.08	28.8	1.62
Composite, selected bran	0.2	2.88	0.73	13.7	0.86	2490*	2.20	24.2	1.91
WHEAT FLOUR									
WP, unfortified white bread flour	8	0.15	0.06	4.2	0.30	80	0.40	1.5	0.15
WP, fortified white bread flour	214	0.58	0.17	6.1	0.55	360	NT	NT	NT
FS, unfortified white bread flour	0.2	0.33	0.07	6.3	0.41	190	0.44	1.0	0.16
FS, fortified white bread flour	179	0.58	0.16	7.4	0.53	580	NT	NT	NT
OR, unfortified white bread flour	4	0.40	0.02	4.8	0.36	130	0.52	2.6	0.16
OR, fortified white bread flour	241	0.60	0.15	6.2	0.55	340	NT	NT	NT
Composite, unfortified white bread flour	ND	ND	0.03	6.4	0.45	240	0.48	2.3	0.28
Composite, fortified white bread flour	216	0.54	0.16	7.3	0.51	300*	NT	NT	NT
BREAD									
Unfortified white bread	0.2	ND	0.01	4.3	0.95	20	0.33	2.3	0.06
Fortified white bread	109	ND**	0.09	6.0	1.73	80	NT	NT	NT
Unfortified brown bread	1.1	ND	0.01	5.8	0.60	80	0.33	5.1	0.12
Fortified brown bread	84	ND**	0.11	8.2	2.13	130	NT	NT	NT

* A calculated mean value was used in the Condensed Food Composition Tables (CFCT) and not the above reported analysed composite values. ND = Not detected, NT = Not tested

**For the CFCT assumptions were made for the thiamin content of fortified white and brown bread, based on the values for the fortified white and brown bread flour, respectively. Adjustments were made for moisture content and retention factors were used to compensate for the effect of heat on thiamin

Table 6. MINERALS: Values for wheat, bran, white bread flour and bread.

Minerals Unit per 100 g edible food	Ca mg	Fe mg	K mg	Na mg	Zn mg	Mn µg	Cu mg	P mg	Mg mg	Cr µg	Se µg
WHOLE WHEAT, RAW											
WP, whole wheat	6	1.8	291	8	1.84	190.71	0.26	132	58	4.8	3.2
FS, whole wheat	8	3.4	273	5	2.46	218.12	0.40	125	67	6.5	1.8
OR, whole wheat	6	1.4	318	8	1.68	144.19	0.20	155	67	5.6	2.0
Composite, whole wheat	8	2.4	297	8	1.92	193.21	0.27	145	68	4.9	1.8
SELECTED BRAN											
WP, selected bran	20	7.8	1218	26	6.88	1032.64	0.83	885	332	6.2	3.9
FS, selected bran	33	10.1	1055	17	9.39	1058.59	0.96	795	362	5.7	3.7
OR, selected bran	31	6.1	1298	18	6.45	761.70	0.63	1070	415	6.5	1.6
Composite, selected bran	27	6.9	1115	18	6.90	888.60*	0.86	859	355	7.0	4.2
WHEAT FLOUR											
WP, unfortified white bread flour	3	0.9	109	6	2.02	22.59	0.12	45	14	5.8	2.5
WP, fortified white bread flour	3	4.2	104	4	1.99	70.68	0.09	46	14	5.7	1.9
FS, unfortified white bread flour	3	1.3	97	5	0.64	23.94	0.14	37	14	6.4	1.4
FS, fortified white bread flour	3	3.4	90	5	1.54	24.96	0.12	37	14	5.9	3.5
OR, unfortified white bread flour	3	0.5	113	6	0.57	20.00	0.09	54	17	5.9	1.0
OR, fortified white bread flour	4	2.3	108	5	1.39	16.54	0.09	51	16	5.1	1.3
Composite, unfortified white bread flour	3	1.1	103	3	0.55	22.95	0.10	45	15	5.3	1.9
Composite, fortified white bread flour	4	2.9	100	5	1.46	21.58	0.10	43	14	5.9	2.6
BREAD											
Unfortified white bread	12	1.7	133	655	1.03	56.27	0.12	53	20	6.3	1.5
Fortified white bread	16	3.6	214	653	2.15	75.73	0.15	96	43	5.8	1.5
Unfortified brown bread	14	1.9	223	686	1.40	115.52	0.16	90	44	5.6	2.3
Fortified brown bread	14	4.1	227	648	4.49	117.64	0.19	93	44	6.5	2.2

*A calculated mean value was used in the Condensed Food Composition Tables and not the above reported analysed composite values.

Table 7. SUGARS: Values for wheat, bran, white bread flour, brown bread flour and bread.

Sugars Unit per 100 g edible food	Sucr g	Fruc g	DP-1 g	DP-2 g	DP-3 g
WHOLE WHEAT, RAW					
WP, whole wheat	0.45	N/A	ND	1.39	0.40
FS, whole wheat	0.76	N/A	ND	1.66	0.31
OR, whole wheat	0.79	N/A	ND	1.33	0.59
Composite, whole wheat	0.84	N/A	ND	3.45	0.63
SELECTED BRAN					
WP, selected bran	2.48	0.36	0.69	ND	0.88
FS, selected bran	2.57	N/A	0.88	1.07	0.86
OR, selected bran	2.95	N/A	0.75	ND	0.75
Composite, selected bran	2.86	N/A	0.71	1.22	0.70
WHEAT FLOUR					
WP, unfortified white bread flour	N/A	N/A	ND	17.90	ND
WP, fortified white bread flour	NT	NT	NT	NT	NT
FS, unfortified white bread flour	N/A	N/A	ND	11.28	ND
FS, fortified white bread flour	NT	NT	NT	NT	NT
OR, unfortified white bread flour	N/A	N/A	ND	13.47	ND
OR, fortified white bread flour	NT	NT	NT	NT	NT
Composite, unfortified white bread flour	ND	N/A	ND	10.37	0.38
Composite, fortified white bread flour	NT	NT	NT	NT	NT
SASKO, unfortified white bread flour	0.48	N/A	ND	12.57	0.49
SAGL, unfortified white bread flour	ND	N/A	ND	12.09	0.45
SASKO, unfortified brown bread flour	0.68	N/A	ND	5.71	ND
SAGL, unfortified brown bread flour	0.40	N/A	ND	5.93	0.45
BREAD					
Unfortified white bread	ND	0.84	ND	3.47	0.34
Fortified white bread	NT	NT	NT	NT	NT
Unfortified brown bread	ND	N/A	ND	1.22	ND
Fortified brown bread	NT	NT	NT	NT	NT

DP = Degree of Polymerization, N/A = Not Applicable, ND = Not detected, NT = Not tested

Table 8. AMINO ACIDS: Values for wheat, bran, white bread flour, brown bread flour and bread.

Amino Acids	ALA	ARG	ASP	GLU	GLY	HIS	ILE	LYS	LEU	PHE	PRO	SER	THR	TYR	VAL	CYS	TRP	MET
Unit per 100 g edible food	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g
WHOLE WHEAT, RAW																		
WP, whole wheat	0.416	0.545	0.519	3.311	0.473	0.325	0.409	0.269	0.737	0.528	1.142	0.542	0.332	0.248	0.495	0.400	0.148	0.196
FS, whole wheat	0.487	0.669	0.628	4.151	0.563	0.346	0.498	0.331	0.895	0.659	1.462	0.636	0.364	0.391	0.596	0.394	0.145	0.202
OR, whole wheat	0.406	0.557	0.505	3.225	0.477	0.281	0.394	0.255	0.710	0.507	1.087	0.509	0.284	0.321	0.481	0.393	0.152	0.154
Composite, whole wheat	0.435	0.593	0.549	3.775	0.507	0.335	0.442	0.304	0.786	0.566	1.260	0.582	0.357	0.264	0.522	0.320	0.172	0.148
SELECTED BRAN																		
WP, selected bran	0.729	0.975	0.979	2.800	0.781	0.426	0.446	0.629	0.804	0.530	0.823	0.608	0.475	0.310	0.643	0.341	0.226	0.132
FS, selected bran	0.860	1.208	1.161	3.579	0.925	0.507	0.555	0.706	0.984	0.674	1.047	0.722	0.538	0.403	0.798	0.333	0.249	0.206
OR, selected bran	0.701	0.984	0.920	2.693	0.744	0.421	0.437	0.615	0.774	0.521	0.780	0.560	0.448	0.357	0.635	0.352	0.272	0.158
Composite, selected bran	0.689	0.973	0.981	2.842	0.711	0.433	0.441	0.530	0.813	0.543	0.876	0.609	0.476	0.328	0.638	0.339	0.237	0.110
WHEAT FLOUR																		
WP, unfortified white bread flour	0.358	0.485	0.418	3.596	0.410	0.308	0.416	0.222	0.749	0.541	1.366	0.578	0.340	0.273	0.460	0.283	0.123	0.146
FS, unfortified white bread flour	0.457	0.563	0.491	4.378	0.529	0.385	0.498	0.257	0.894	0.669	1.697	0.798	0.406	0.367	0.552	0.371	0.135	0.225
OR, unfortified white bread flour	0.330	0.425	0.313	3.420	0.400	0.250	0.383	0.215	0.691	0.516	1.206	0.505	0.270	0.302	0.436	0.375	0.127	0.163
Composite, unfortified white bread flour	0.350	0.469	0.404	3.816	0.418	0.285	0.426	0.210	0.762	0.563	1.301	0.545	0.287	0.342	0.475	0.283	0.135	0.189
SASKO, unfortified white bread flour	0.326	0.438	0.408	3.922	0.384	0.308	0.396	0.218	0.708	0.525	1.295	0.525	0.328	0.221	0.439	0.268	0.140	0.180
SAGL, unfortified white bread flour	0.326	0.413	0.399	3.537	0.371	0.308	0.387	0.216	0.698	0.517	1.244	0.488	0.314	0.369	0.443	0.288	0.138	0.198
SASKO, unfortified brown bread flour	0.376	0.534	0.466	3.840	0.435	0.338	0.414	0.260	0.731	0.533	1.254	0.540	0.345	0.234	0.467	0.343	0.160	0.182
SAGL, unfortified brown bread flour	0.357	0.483	0.453	3.704	0.380	0.302	0.302	0.176	0.693	0.517	1.198	0.514	0.320	0.275	0.445	0.281	0.157	0.199
BREAD																		
Unfortified white bread	0.257	0.338	0.314	2.661	0.297	0.217	0.288	0.160	0.528	0.381	0.892	0.373	0.234	0.220	0.331	0.315	0.102	0.144
Unfortified brown bread	0.266	0.343	0.321	2.563	0.304	0.219	0.282	0.183	0.509	0.372	0.861	0.372	0.231	0.209	0.326	0.311	0.110	0.113