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REVIEW ARTICLE

Determination of macronutrient compositions in selected, frequently consumed cereals, cereal based foods, legumes and pulses prepared according to common culinary methods in Sri Lanka

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Abstract Cereal grains, legumes and pulses comprise the largest proportion in a typical South-Asian diet plate. This research is mainly focusing on determining the macronutrient composition of major cereals, legumes and pulses commonly consumed in local Sri Lankan cuisine, in their cooked form. White samba, White Basmati, Red Kekulu and Nadu rice were selected as the main rice varieties and in addition maize, and wheat, finger millet flour-based foods too were analyzed. Red cowpea, green gram, chickpea and soya bean based foods were analyzed for macronutrient compositions as they are more frequently consumed by the local population, while the most preferred curry item; 'lentils', was analyzed along with soya curry; another preferred item by millions of locals. Wheat flour based items like bread were taken into analysis since, they have become the second most preferred food next to rice. Every item was cooked according to the common culinary practices in aim to determine the "realistic nutrient gain". Proximate analysis was carried out according to the AOAC standard guidelines for the determination of moisture, carbohydrate, fat, and protein whereas, insoluble dietary fiber and soluble dietary fiber were determined using enzymatic digestion in vitro models. Results revealed digestible carbohydrate level range from 64.6 ± 5.3 to 74.6 ± 7.2% among tested rice varieties, while protein content varies from 5.6 ± 2.2 to 8.9 ± 2.6. Insoluble dietary fiber was high in boiled raw rice (9.8 ± 0.2) and low in boiled White Basmati. Amongst tested leguminous beans, pressure cooked red cowpea elicited the highest protein level (24.5 ± 2.3%), while pressure cooked green gram had the lowest protein content (20.0 ± 0.6%). Pressure cooked chick pea was having higher insoluble dietary content (14.8 ± 1.3%) compared to other beans. Soybean curry elicited the highest protein (36.6%) and fat content (8.2%) among all the tested varieties. Pittu (puttu) and roti varieties made with wheat flour and finger millet flour resulted considerably higher levels of digestible fiber compared to roti made with whole wheat flour. It can be concluded that typical Sri Lankan diets are rich in fibre and protein, while they provide excellent macronutrient profiles due to the proper complementary mixing of food ingredients.

Keywords Cereals · Pulses · Macronutrients · Digestible carbohydrates · Cooking methods

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Introduction

Food consumption patterns in Sri Lanka have gone through dramatic changes over the last 2 decades. It is linked with many factors like income, prices of the food, availability and accessibility, and urbanizing lifestyles of people (Herath et al. 2007). Rice (*Oryza sativa L.*) is both, the most consumed staple food (Ranawake et al. 2013) and principal cereal grain cultivated in Sri Lanka. In addition to rice, there are several other cereals, cereal based foods and leguminous pulses, which also are very common in a typical Sri Lankan main meals. Whole grains are rich in nutrients and phytochemicals such as antioxidants, dietary fibre, vitamins, minerals and fat (Slavin 2003). Rice being the staple food in the Asian region, has a great contribution to fulfill the dietary energy, fat and protein requirements of consumers. For instance, rice contributes to nearly 50% of the energy and 40% of protein intake in a typical daily diet (Darandakumbura et al. 2013).

On the contrary, wheat bread has become a staple diet in urban areas. Together they account for 65% of the energy intake and the contribution form rice has been decreased from 80% in 1980 to 46% in 1990 (Herath et al. 2007). Although the usual white bread is categorized under high Glycemic Index (GI) foods, incorporation of lentils can reduce the GI values of wheat bread based meals from high to medium GI category (Hettiaratchi et al. 2009). Yet, the consumption of rice versus bread is shifting time to time depending on the wheat flour price. Increased refined wheat flour consumption has been raising many health concerns. Recent studies implies that there is a definite upward trend in the prevalence of diabetes mellitus in Sri Lanka, while in 1990 diabetic was 2.5% and it has increased up to 14.2% in males and 13.5% in females by 2005 (Katulanda et al. 2006) while urban areas (16.4%) are more prone to diabetes compared to rural areas (8.7%) (Ekanayake 2010). Moreover, it emphasized that high prevalence in diabetes is correlated with high consumption of sugar, white rice, wheat flour and lack of exercise (Ekanayake 2010; Hettiaratchi et al. 2009).

According to Rajapakse et al. (2000), until 1950's there were only traditional rice varieties available for local consumption. They tend to digest slowly and give better satiety for an extended time compared to improved varieties (Pathiraje et al. 2010). Both physiochemical properties such as, grain color, grain size, grain shape and gelatinization characteristics and nutritional attributes influence the consumer preference (Abeysekera et al. 2017). Research carried out in Kandy district reveals that majority of the consumers preferred red parboiled rice whereas, consumers in southern coastal areas also preferred raw red rice varieties. People in urban areas preferred parboiled white rice, which indicates that there is a regional difference in the consumption of rice.

Rice varieties significantly vary in their nutritional aspects. Red rice is believed to have better nutritional qualities; higher fiber level and lower glycemic index compared to white rice. Hettiarachchi et al. (2001) suggests that red parboiled varieties have significantly lower glycemic index than white raw rice. He further states that red parboiled varieties and Bg 350 can be recommended for diabetic patients due to their slow digestion of dietary carbohydrates. Hence, color of the rice variety is not yet considered as a good predictor to determine the glycemic index of rice varieties (Hettiarachchi et al. 2001; Pathiraje et al. 2010). Glycemic index of red rice varieties varies from 56 to 73 whereas, in white rice it ranges from 62 to 68. In addition, some of the red rice varieties supposed to have medicinal and favorable antioxidant properties (Rajapakse et al. 2000).

Among the foods studied, boiled legumes (chickpea, cowpea, mung beans), roti varieties also play a major role in local diets. Consumption of leguminous pulses elicit a negative trend while, cereal consumption grows at an average annual rate of 3.37%. It was estimated that pulses consumption was at level of 21 g per person per day had been reduced by 4.76% in 2007 (Sri Lanka Pulses consumption, 1992–2007—knoema.com 2011). However, fewer number of studies have been conducted to identify the nutritional composition and their contribution towards the health and other aspects of the local population.

At present, people apt to deviate from traditional dietary patterns rapidly (Jayasinghe and Ranaweera 2015), and therefore, it is of utmost importance to imply their nutritional values. Previous research has showed that red rice is more health beneficial compared to white rice and benefits of leguminous grains cultivated traditionally in the country are highly nourished. Yet, we haven't analyzed them in their cooked forms, except in porridge (Senadheera 2016); making it difficult to estimate actual nutrient gains. Despite these efforts, nutrition-based evaluation of cooked grains and pulses, has been infrequently tested with respected to the Sri Lankan consumption patterns and also very few studies discuss the comprehensive evaluation of the macronutrient composition of these foods. Hence, this study was designed to fill that void; to investigate realistic nutrient gains by consuming various cereals, grains and leguminous pulses and food items made by them using common cooking methods. Finding s of this stud will be of importance especially to the vast population living in the South Asian and South-East Asian countries, since they practice similar culinary methods as well as much common food sources as staples.

Materials and methods

Sample preparation

Samples of four rice varieties (*Oryza sativa L.*), including white samba, nadu, red kekulu, and white basmati, chickpea (*Cicer arietinum*), green gram (*Phaseolus aureus*), red cowpea (*Vigna unguiculate*), maize (*Zea mays*), lentil (*Lens esculenta*), soy beans (*Glycine max*), wheat flour (*Triticum aestivum*), kurakkan flour (finger millet; *Eleusine coracana*) and wheat bread were purchased from local supermarkets in different regions in Sri Lanka, and mixed well before post processing. It was noticed that same food bought from different places were slightly different in their size, shape and color. All the foods were prepared according the most common culinary practices in the country. Rice and maize samples were boiled. Chickpea, green gram, and red cowpea were pressure cooked for 10 min at 15 lbs pressure using house hold pressure cooker.

Cereal flours were made into roti and pittu (puttu). Roti dough was made using whole wheat flour and 3:1 ratio of wheat flour and kurakkan flour. Firstly, wheat flour (120 g) was mixed with 50 g of shredded coconut, finely, tablespoon of salt and tablespoon of water. Then, it was well mixed until a firmed dough is formed. A golf ball size dough was taken and rolled gently and it was spread into a 10–12 cm circle with thickness of 2–2.5 mm on a tray. Finally, it was cooked till became golden-brown color. Pittu was also prepared with whole wheat flour and wheat flour, kurakkan flour 3:1 ratio. Wheat flour (approximately three cups) was added with $1^{1/2}$ teaspoon of salt and trickles of hot water was added while mixing, until bread crumbs were formed. Then the mixture was combined with shredded coconut steamed in cylindrical mould (Sri Lanka, house hold cylindrical pittu steamer). Lentil curry and soya curry were prepared by steam cooking. After preparation, they were homogenized by blending (Sri Lanka, house hold grinders; Singer-KA-ELITE). Samples were kept in air tight bottles and stored at room temperature (25 °C) until the analysis. Six replicates were taken from each food.

Determination of proximate compositions

Moisture content was determined by oven drying method where, samples were dried at 105 °C to a constant weight (AOAC 1984). Digestible carbohydrates was determined according to Modified method of Holm et al. (1986); fat content by Majonnier fat extraction method (Croon and Guchs 1980), ash by incinerating in a muffle furnace at 550 °C for 5 h (AOAC 1984) and crude protein content was determined by digestion of the sample using Kjeldhal method. The determination of soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) were done by sequential digestion using acid and phosphate buffer solutions as described in Asp et al. (1983). All analysis was done for six replicates.

Insoluble dietary fibre determination (Asp et al. 1983)

Six samples from each food item were homogenized at 17,300 rpm for 2 min (ULTRA–TURRAX®) in 25 mL of phosphate buffer (pH 6.2). Digestion with 100 µL α-amylase in a boiling water bath at 100 °C for 25 min was carried on followed by the addition of 20 mL of 0.2 M cold HCl (4 °C), after when samples were cooled up to the room temperature. The pH was adjusted to 1.5 (Thermo Electron Corporation Orion 410A+) and mixtures were digested with 0.1 g of pepsin (Fisons, England) at 40 °C in a shaking water bath (EYELA Uni Thermo Shaker NTS-1300) for an hour. After allowing cooling to the room temperature, pH was adjusted to 6.8. Pancreatin 0.1 g (EC No 232-468-9 Sigma-Aldrich, USA) was added to each sample and heated in 40 °C for an hour with continuous shaking. The pH was adjusted to 4.5 and sample mixtures were filtered using No. 02 porosity crucibles. Filtrates were put in separate conical flasks, labeled accordingly for the determination of soluble dietary fibre (3.2.1.5.2). Residues were washed with two 15 mL portions of 95% ethanol and two 15 mL portions of acetone, (EC No 200-662-2-Sigma-Aldrich, USA) respectively. Finally, crucibles were dried at 105 °C until a constant weight was observed followed by incineration at 550 °C for 5 h.

$$\%\ \mathrm{IDF} = \frac{\mathrm{W1} - \mathrm{W2} \times 100}{\text{Weight of the sample}}$$

W1: Weight of the crucible after drying at 105 °C, W2: Weight of the crucible after incinerating at 550 °C

Soluble dietary fibre determination

Absolute ethanol was added to six filtrates separated in the above procedure until each of their EtOH concentration was 76%. Samples covered by Aluminium foils were subjected to incubation at 60 °C for an hour. Samples were filtered using No. 4 filtration crucibles by applying suction force, followed by washing with two 15 mL portions of ethanol and two 15 mL portions of acetone respectively. Crucibles were dried at 105 °C until a constant weight was observed followed by incineration at 550 °C for 5 h.

$$\%\ \mathrm{SDF} = \frac{\mathrm{W1} - \mathrm{W2} \times 100}{\text{Weight of the sample}}$$

W1: Weight after drying at 105 °C, W2: Weight after incinerating at 550 °C

Results and discussion

Results of macro nutrient compositions of mostly consumed cereals and pulses in their post processed form are shown in Table 1. These were calculated on dry weight basis to allow comparison with literature data.

In this study, 15 different cereal and grain based food items were tested in their cooked form for proximate compositions. These items are either consumed as sole foods (boiled chick pea, boiled cowpea, boiled green gram) or incorporated as curries (ex: lentils, soy) with bread or

Table 1 Mean percentage values (Mean ± SD, n = 6) of macronutrient compositions of cereals, cereal based foods, and pulses

Food item	Moisture %	Fat %	Protein %	Mineral or ash %	Carbohydrate %	IDF %	SDF%
Boiled white samba rice	70.1 ± 2.5	2.4 ± 0.7	8.5 ± 2.3	1.8 ± 0.2	74.6 ± 7.2	7.6 ± 0.1	5.0 ± 0.2
Boiled red kekulu	72.2 ± 0.9	2.3 ± 0.5	6.7 ± 1.7	2.3 ± 0.6	72.5 ± 6.0	9.8 ± 0.2	6.1 ± 0.4
Boiled Nadu rice	67.4 ± 2.0	1.8 ± 0.7	5.6 ± 2.2	0.8 ± 0.2	64.6 ± 5.3	8.6 ± 0.7	7.2 ± 0.5
Boiled white basmati	71.6 ± 3.5	3.1 ± 0.8	8.9 ± 2.6	1.0 ± 0.4	74.5 ± 3.7	6.6 ± 1.1	4.8 ± 0.8
Pressure cooked chick pea	63.4 ± 1.2	2.2 ± 0.1	22.4 ± 1.1	3.0 ± 0.6	62.1 ± 2.1	14.8 ± 1.3	6.9 ± 0.2
Pressure cooked green gram	64 ± 3.2	2.6 ± 0.8	20.0 ± 0.6	3.4 ± 0.6	65.9 ± 2.21	7.0 ± 0.7	5.3 ± 0.1
Pressure cooked red cowpea	67.8 ± 4.2	4.4 ± 0.8	24.5 ± 2.3	3.0 ± 0.7	64.6 ± 2.3	7.8 ± 0.3	5.8 ± 0.2
Boiled maize	67.6 ± 2.5	5.4 ± 0.7	4.2 ± 0.3	2.5 ± 0.6	64.6 ± 4.2	9.6 ± 0.7	4.0 ± 0.2
Wheat bread	12.1 ± 2.5	6.9 ± 1.5	12.2 ± 2.0	1.8 ± 0.6	77.6 ± 4.3	3.6 ± 0.3	2.7 ± 0.5
Pittu (wheat flour)	50.5 ± 2.3	6.8 ± 0.4	8.2 ± 0.6	1.2 ± 0.6	69.2 ± 5.0	8.9 ± 1.1	6.1 ± 0.4
Pittu (wheat + Kurakkan flour) 3:1	46.5 ± 3.5	6.3 ± 0.9	4.1 ± 0.6	2.2 ± 0.5	61.9 ± 4.6	14.5 ± 0.3	8.8 ± 0.5
Roti (wheat flour)	26.5 ± 1.5	7.1 ± 0.5	12.7 ± 0.6	2.1 ± 0.5	57.8 ± 4.3	8.5 ± 0.3	6.0 ± 0.5
Roti (wheat + Kurakkan flour) 3:1	25.9 ± 3.6	7.0 ± 0.6	10.2 ± 0.3	2.8 ± 0.8	52.8 ± 4.7	15.2 ± 0.3	7.9 ± 0.5
Lentil curry	85.3 ± 4.5	4.6 ± 0.2	14.4 ± 0.2	2.6 ± 0.2	54.2 ± 4.8	8.6 ± 0.2	5.8 ± 0.8
Soy curry	86.7 ± 3.3	8.2 ± 1.2	36.6 ± 1.9	2.8 ± 0.7	34.6 ± 3.6	9.3 ± 0.7	6.7 ± 0.4

IDF insoluble dietary fiber, *SDF* soluble dietary fiber

rice (ex: bread—lentil meal) in Sri Lanka. Other than that, boiled maize is often used as a snack and is not commonly used in daily consumption.

Rice and bread being the most common sources of carbohydrates consumed by locals. According to the results obtained, white bread has the highest carbohydrate level (77.6 ± 4.3%) followed by boiled white samba (74.6 ± 7.2) and boiled white basmati (74.5 ± 3.7). Among tested rice varieties, boiled Nadu rice has the lowest carbohydrate level (64.6 ± 5.3%). According to previous studies, digestible carbohydrate content of different rice varieties ranged from 74 to 84%, but Nadu rice has low digestible carbohydrate level maybe because it contains more resistant starch. There are no sufficient evidences about Nadu rice to prove that fact from previous studies and therefore, need further research.

Protein content has varied from 5.6 ± 2.2 to 8.9 ± 2.6%. However, according to the FAO report (1993), protein content of rice can vary from 6 to 15% and is largely affected by environmental conditions, cropping season, rate and time of nitrogen fertilization, water management, cropping practices etc.

Legumes include peas, beans, lentils, peanuts, and other podded plants that are used as food (Messina 1999) are more popular among Asian countries as they are economical source of protein. In Sri Lanka, legumes like dhal, soybean are often consumed as a combination with cereals as they complement each other to provide a complete amino acid profile. Mung Kiribath (meal comprising rice and green gram), rice with dhal curry are such examples, that are very common in Sri Lankan cuisine. Dhal is cooked with coconut milk until it reaches soft consistency and then seasoned with spices and condiments. Other legumes like mung bean, green gram and cow pea are boiled and directly consumed with grated coconut. However, the effect of different cooking patterns on the nutritional composition are poorly documented. According to the literature, protein content of beans varies from 20 to 30%. Macronutrient composition of selected legume beans are shown in Table 1. Their protein content has been ranged from 22.4 ± 1.1 to 24.5 ± 2.3. Although beans are high in protein, the quality of protein is not estimated properly. However, it is emphasized that due to lack of sulfur containing amino acid, these proteins may have low digestibility and poor protein efficiency ratio (Messina 1999).

Soybean is especially popular among low and middle-income families as a substitute for meat and fish as an inexpensive source of protein. Vegetable soybean is more commonly available in preprocessed form (Textured vegetable protein) and generally known as soya meat among consumers. It is consumed as a curry often with rice. Like other legumes soybeans are rich in variety of nutrients. Besides its high protein value (36.6 ± 1.9%), it is also high in dietary fibre, variety of micronutrients and phytochemicals. According to the data (Table 1), soya curry contains little more fat (8.2 ± 1.2%) than usual, is due to the addition of coconut milk during cooking.

Both pittu and roti made with finger millet (Kurakkan) flour (wheat + Kurakkan flour 3:1) has the highest content of insoluble and soluble dietary fibre, 14.5 ± 0.3/ 8.8 ± 0.5, 15.2 ± 0.3 and 7.9 ± 0.5, respectively.

Insoluble dietary fiber was high in roti (15.2 ± 0.3%) in which wheat flour and Kurakkan flour (*Eleusine coracana*) had been incorporated to 3:1 ratio, while the roti made with wheat flour has 8.5 ± 0.3% of insoluble fibre, while wheat bread has the lowest (3.6 ± 0.3%) amount. It reveals that 3:1 addition of Kurrakkan has dramatically increased the insoluble dietary fibre % in Kurakkan roti.

The results also reveal that the cooking method has a lower impact on their natural macronutrient composition compared to the drastic changed that happens with respect to micronutrients. Although it helps in gelatinization and thereby, easy digestion; boiling and pressure cooking has incorporated high moisture content into food particles, replacing the beneficial nutrient concentration in a typical meal portion.

Incorporation of coconut milk when preparing curries/gravies have contributed to the fat content in lentil, soya curries (Table 1).

Data of macronutrient compositions can be used by industrial food processors and dietitians for their respective purposes. For an example; based on the digestible carbohydrate content, a dietitian would be able to select the most suitable food item, recommend the most appropriate cooking method for patients and the numerical data can be used for proportional diet planning calculations. Depending on the fibre composition, industrial processers would be able to decide which types of cereals/grains are ideal to process whole grain flours and which types are ideal for refining.

Hence, these sort of data bases have a wide range of long-term use

Conclusion

Frequently consumed cereals and grains are excellent sources of digestible carbohydrates, when cooked. Leguminous pulses are great sources of proteins and dietary fibre. It is of utmost importance to use proximate composition data of "cooked" food in order to be aware of 'realistic nutrient gains' from daily meals.

Recommendations

Dietitians and Food Processors may use these data in order to formulate diet plans, and novel food products respectively; as they reveal of realistic availability of macronutrients of cereals, grains, pulses after being cooked.

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