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Original Research Article

Nutrients and antinutrients of ragi and wheat as influenced by traditional processes

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A B S T R A C T

Nutritional deficiencies such as proteins, vitamins and minerals are widespread in most developing countries and hence, imperative to obtain foods with superior nutritive value. Since the impact of various traditional processes on different cereals and legumes is diverse, present work focuses on influence of various combinations of processes on nutrients and antinutrients of ragi and wheat. Significant difference in nutrients and antinutrients among raw and processed ragi and wheat was observed. Pressure cooking, fermentation and germination, potentially increasing the major nutrients. There was significant reduction of phytic acid by 61.5 and 51.8% in roasted ragi and wheat respectively. Total polyphenols significantly reduced by 65.8 and 87.1% respectively in blanched ragi and roasted wheat. A significant reduction of tannins by 73.6 and 85.1% was found in soaking followed by pressure-cooked ragi and fermentation followed by germinated wheat respectively. Flavonoids reduced by 51% in germinated and kilned ragi and wheat, while 61.5 and 52.3% reduction in trypsin inhibitors was noticed in roasted and pressure-cooked ragi and pressure-cooked wheat respectively. Antioxidant activities by DPPH scavenging and reducing power assay were weak in all the samples. It is suggested to adopt suitable process for highest nutrient retention and antinutrient reduction for composite food preparations.

Keywords

Proximate composition, Ragi (*Eleucine coracana*), Wheat (*Triticum aestivum*), Antinutrients, Processing

Introduction

Over three billion people are currently malnourished globally, due to inconsistent supply of foods with essential nutrients to meet daily needs (Welch, 2005). The potential benefits of cereals as nutritionally- balanced diet, help in eliminating deficiency disorders (Zuzana et al., 2009). Cereals play an important role in composite food preparation due to their cheapest sources of food energy contributing a high percentage of calories (>56%) and proteins (50%) in Indian diets (Mahajan & Chattopadhyay, 2000). All current dietary guidelines have cereal foods as largest component of recommended daily intake (NHMRC, 2003), as they are good source of vitamins and a number of minerals, notably iron, zinc, magnesium and potassium. Earlier reviewers also report that consumption of grains exerts cardioprotective influence (Kushi et al., 1999).

Finger millet (*Eleusine coracana*), also known as ragi is a good source of carbohydrate, protein, dietary fibre and minerals, and an important staple food for people under low socio- economic group (Sripriya, et al., 1997) and those suffering from metabolic disorders like diabetes and obesity (Mathanghi & Sudha 2012). It is important because of its excellent storage properties and nutritive value (Shashi et al., 2007). Its dietary fibre and mineral content is markedly higher than wheat, rice, and fairly well balanced protein (Ravindran, 1991). Wheat (*Triticum aestivum*) is largely consumed in various forms like breads, biscuits, cookies, cakes, pasta, noodles and is the major source of dietary energy and protein for humans (Hussain et al., 2004). A number of studies have shown their protective role against several nutrition-related diseases such as type-2 diabetes (Murtaugh et al., 2003; Pereira et al., 2002), cardiovascular diseases (Jacobs & Gallagher, 2004) and certain cancers (Larsson et al., 2005). In addition to richest source of nutrients, these cereals also posses certain antinutrients like phytic acid, polyphenols, tannins, trypsin inhibitors etc, (Hag et al., 2002). Antinutrients are substances that reduce nutrient digestion, absorption and utilization and may produce other adverse effects in the ingesting humans and animals. These compounds are naturally produced in the plants during their normal metabolism (Akande et al., 2010).

Processing affects antinutritional factors such as fibre, phytate and enzyme inhibitors, which in turn can enhance or reduce the bioavailability of micro and macro- nutrients (Nestares et al 1997). Hence an attempt was made to study the effect of various combinations of traditional processing on nutrients and antinutrients of ragi and wheat.

Materials and Methods

Whole ragi and wheat procured from local market were cleaned to remove broken grains and other extraneous materials. All standard chemicals procured from Sigma Chemicals (USA) and other chemicals, reagents, solvents used in this study were of analytical, extra pure and HPLC grade.

Sample preparation

25g each of ragi and wheat were subjected to nine different processes given below each of the tables.

Proximate analysis of raw and processed ragi/wheat

Total sugar estimation was carried out by phenol-sulphuric acid method (Dubois et al., 1956) by preparing a standard graph for D-glucose with a working range of 0-25 µg/ml. Total protein, total lipid, minerals, moisture (AOAC, 2007) and total fibre (Maynard, 1970) estimations were carried out.

Antinutrients estimation

The phytic acid contents of all the samples were estimated by the method of Gao et al., (2007) using sodium phytate (Sigma chemicals, USA) as standard. Total polyphenol extraction was made by the method of Chethan & Malleshi, (2007) and estimation by spectrophotometric method of Singleton et al., (1995) using gallic acid (Sigma chemicals, USA) as standard. The results are expressed as milligram gallic acid equivalents (mg GAE). Tannins were estimated by the method of Price et al., (1978) and flavonoids by Zhishen et al., (1999) using catechin (Sigma chemicals, USA) standard. The results are expressed as milligram catechin equivalents (mg CAE). Trypsin inhibitor estimation was carried out by the method of Hamerstrand et al., (1981) using trypsin (Sigma chemicals, USA) as a substrate.

Antioxidant properties

Antioxidant activities of polyphenol extract was tested through DPPH free radical scavenging activity by the method of De Ancos et al., (2002) and reducing power assay by the method of Oyaizu, (1986).

HPLC analysis of carotenoids

Carotenoids were separated on a C-18 Supelco HS20419BQ column (25 x 4.6 mm internal diameter). Mobile phase for separation of carotenoids contained acetonitrile: methanol: dichloromethane (60:20:20, v/v/) and 0.1 % ammonium acetate. Samples injected (20 µl) were maintained under isocratic condition at a flow rate of 1ml/ min. β-carotene and lutein obtained from Sigma Chemicals (USA) were used as external standards.

Statistical analysis

Data, expressed as mean ±SD was statistically analyzed using one-way ANOVA (Steel & Torrie, 1990). Duncan's multiple tests were used to compare means and significance was accepted at $p \leq 0.05$.

Results and Discussion

Proximate composition of raw and processed ragi

Ragi and wheat grains were subjected to nine different combinations of domestic processes and maintaining one sample as control (raw, R) without any process. The proximate composition of raw and differently processed ragi is given in table 1. Total sugar content ranged from 55.8 to 79.41% with minimum in fermented (SFM) and maximum in pressure-cooked (PM) ragi. Crude protein content among raw and processed ragi ranged between 3.1 and 13.5%, where the lowest was in soaked sample and significantly high in germinated and kilned sample, while raw sample had 6.8%. Total fat content of raw and processed ragi ranged from 1.0 to 1.8%. Raw sample had highest fat with reduced crude fat content in all other samples with minimum in pressure-cooked sample. Ash content ranged from 1.8 to 2.4% with highest in blanched and soaked samples while lowest in roasted and fermentation followed by germinated samples. Total fibre content of all samples ranged from 2.02 to 3.66%, with highest in fermentation followed by germinated and kilned ragi and lowest in roasted sample. Moisture content ranged from 2 to 8%, where highest was in raw ragi and all other samples showed reduced moisture contents with lowest in roasted sample.

Proximate composition of raw and processed wheat

The proximate composition of raw and processed wheat is represented in table 2. Total sugars of all wheat samples ranged from 63.5 to 80%, where fermentation followed by germination and kilning had significantly higher sugar content than the raw sample. Crude protein content of raw and differently processed wheat samples ranged from 6.39 to 11.88%. Germination followed by kilned wheat had slightly higher protein content than raw sample (11.18%). The total fat content ranged from 1.1 to 2.1%. Similar to ragi sample, wheat also showed decreasing trend of fat after processing. Total fibre among the samples ranged from 1.03 to 2.11%. Although pressure-cooked sample showed higher fibre content, it was not significant than raw sample. Lowest crude fibre was in fermented wheat. Ash content ranged from 1 to 2% among the samples with highest in fermented and lowest in soaked sample. Moisture ranged from 4 to 8% with highest in roasting followed by pressure-cooked and soaked sample.

Mineral composition of raw and processed ragi

Mineral content of raw and processed ragi is given in Table 3. Eight minerals such as Ca, Mg, Cu, Mn, Fe, Zn, K and Na were estimated and found that raw ragi sample had 280.6, 350, 71, 246, 4.97, 2.56, 5.34, 0.83 mg/100g respectively. There was variation in each of the element among different processings. Significantly, higher Ca (343.3 mg/100g) and Mg (1576 mg/100g) were found in soaking followed by pressure-cooked sample. Copper content varied among the samples but significantly higher in blanched sample (1837 mg/100g). There was no significant variation in Mn content among the processes but slightly higher in blanched sample (281.7 mg/100g) than raw (246 mg/100g). Iron was higher in all the samples and significantly higher (51.3 mg/100g) in fermentation followed by germinated sample. There was no significant variation in the Zn content among samples. Soaked sample showed slightly higher (2.68 mg/100g) Zn than the raw (2.56 mg/100g). Potassium content of all the processed samples except blanching (6.65 mg/100g) was lower than raw sample (5.34 mg/100g). There was insignificant variation in Na content of all the samples. Roasting followed by pressure-cooked samples showed slightly higher Na content (1.4 mg/100g) than raw ragi (0.83 mg/100g).

Mineral composition of raw and processed wheat

Table 4 represents mineral content of raw and processed wheat. Calcium content was high in all processed samples and highest (187.16 mg/100g) in fermentation followed by germinated wheat than raw (105.84 mg/100g). Magnesium content varied among the samples but significantly higher (16.07 mg/100g) in pressure-cooked wheat. Copper also varied among the samples but highly significant amount was in blanched sample (2.65 mg/100g) while the raw wheat had 0.64 mg/100g. There was variation in Mn content of all the samples and slightly higher (4.10 mg/ 100g) in roasting followed by pressure-cooked sample. Iron also varied among the samples with highest in fermented sample (5.52 mg/ 100g). All the samples showed slightly higher zinc than raw wheat sample (2.31 mg/ 100g) and the highest was in pressure-cooked sample (3.78 mg/ 100g). Potassium content ranged from 2.84 to 6.52 mg/ 100g where the highest was in roasting followed by pressure-cooked sample. Sodium content ranged from 0.55 to 1.41 mg/ 100g with the highest in roasting followed by pressure-cooked wheat.

Carotenoid content of raw and processed ragi and wheat

Total carotenoid content of raw and processed ragi and wheat were estimated through HPLC using β- carotene and lutein as standards and the results are given in tables 5 and 6. The result showed that the total carotenoids with respect to lutein, reduced in all the processed ragi samples when compared to its raw (43.82 μg/g). Highest retention (0.25 μg/g) of lutein was observed in pressure-cooked sample, while that in raw sample was 0.33 μg/g. Total carotenoid retention was high (34.27 μg/g) in soaking followed by pressure-cooked ragi sample. Total carotenoid was high (68.7 μg/g) in raw wheat sample while highest (67.7 μg/g) and lowest (5.58 μg/g) retentions were noticed in germination followed by kilned and fermented samples respectively. All the processed samples showed reduced lutein and β- carotene content than their respective raw samples (4.27 and 4 μg/g).

Antinutrients of raw and processed ragi

Antinutrients such as phytic acid, total polyphenols, tannins, flavonoids and trypsin inhibitors were estimated and results are summarized in table 7. Raw ragi had highest phytic acid of 685 mg/100g while there was reduction in other processed samples. Significant reduction of 61.5% was observed in roasted sample. Total polyphenols in raw ragi sample was found to be 298 mg GAE/ 100g, with a significant reduction of 65.8% in blanched sample. Highest tannins (18.75 mg CAE/ 100g), flavonoids (23.68 mg CAE/ 100g) and trypsin inhibitors (102.6 mg/g) were found in raw ragi. All the processes showed reduction in tannins, flavonoids and trypsin inhibitors than their respective raw sample. A significant reduction of 73.6% tannins was found in soaking followed by pressure-cooked sample, 51% reduction of flavonoids in germinated and kilned sample and 61.5% reduction in trypsin inhibitors of roasting followed by pressure-cooked ragi was observed.

Antinutrients of raw and processed wheat

Table 8 summarizes antinutrients such as phytic acid, total polyphenols, tannins, flavonoids and trypsin inhibitors of raw and processed wheat. Raw wheat had highest phytic acid content of 440 mg/100g and 51.8% reduction was observed in roasted sample. Total polyphenol content was reduced upto 87.1% in roasted sample when compared to raw ragi (379 mg GAE/ 100g). Tannin content was high (8.65 mg CAE/ 100g) in raw sample while highest reduction of 85.1% was in fermentation followed by germination. High (36.3 mg CAE/ 100g) flavonoid content was in raw sample, while a reduction of 51% was observed in germinated and kilned wheat. There was 52.3% reduction in trypsin inhibitors in pressure-cooked sample than raw wheat sample (226.3 mg/g).

Antioxidant activity of raw and processed ragi and wheat

Antioxidant activity of raw and processed ragi was estimated and results are summarized in table 9. A strong IC_{50} value of 0.74 μg/ml for DPPH free radical scavenging activity and highest [0.875 OD_{700} (5 μg GAE)] reducing power activity was found in raw ragi sample, while blanched sample had weak IC_{50} (3.77 μg/ml) and reducing power activity [0.407 OD_{700} (5 μg GAE)]. Table 10 represents the antioxidant activities of raw and processed wheat. Raw wheat had strong IC_{50} value and highest reducing power activity of 0.47 μg/ml and 1.11 OD_{700} (5 μg GAE) respectively, while roasted wheat had weak IC_{50} of 3.09 μg/ml and low reducing power activity of 0.102 OD_{700} (5 μg GAE).

Scientific studies have established that processes such as cooking, dehulling, soaking, fermentation and germination improve nutritional quality of food products by reducing or eliminating anti-nutrients in them (Oboh et al., 2000). Flour from germinated seeds is reported to have better nutritional properties than flour from non-germinated cereals (Lorenz, 1980). Milled whole grains can be nutritionally superior to intact grains for human consumption because poor digestible compounds are removed during milling process and nutrient bioavailability is enhanced (Slavin et al., 2000).

Nutritionally, finger millet is a good source of calcium, other minerals and fibre. In the present study, highest total sugar was observed in pressure-cooking that may facilitate hydrolysis of polysaccharides and their addition to soluble fraction. Reduced carbohydrate content was observed in fermentation followed by malted ragi, which is attributed to hydrolysis of polysaccharides by both alpha and beta amylases of fermenting microbes and their subsequent utilization by them and also by the grain itself during growth metabolic activities (Bernfeld, 1962). This is in agreement with earlier findings (Sripriya et al., 1997; Fasasi, 2009).

The total protein of raw and processed ragi ranged from 3.1 to 13.5%, a similar range has been reported earlier (Ravindran, 1991; Vadivoo et al., 1998). There was 4- fold increase in fermentation followed by germination. This may be due to microbial enzyme activation and hence protein synthesis. An improvement in the content and quality of cereal proteins by fermentation have been reported (Chavan et al., 1988). The lowest protein content (3.1%) in soaked sample may be due to leaching of soluble protein fractions into soaking water.

The crude fat content of raw and processed ragi ranging from 1 to 1.8% is almost similar to the range that was reported earlier by Malleshi & Desikachar, (1986). Decline in fat content upon heat treatment is due to starch-lipid complex formation that are resistant to lipid extraction (Camire, 2001)). Low fat content reported in all the processed samples is beneficial due to their increased shelf life by decreasing the chances of rancidity (Vadivoo et al., (1998).

Total fibre content was high (3.66 %) in fermentation followed by germinated ragi and low (2.02 %) in roasted sample when compared to control. Same level of fibre (3.7%) has been reported earlier (Joshi & Katoch, 1990). The high total fibre in fermentation followed by germinated sample is due to sugar utilization in the seed for metabolic sprouting activity leaving fibrous seeds behind (Ikenebomah et al., 1986). It was observed that the fibre composition of flours differ with the refined flour containing no lignin and much less insoluble fibre compared to whole grain flour (Joanne et al., 2001).

The ash content of raw and processed ragi ranged from 1.8% in roasted and fermentation followed by germinated sample to 2.4% in blanched and soaking followed by pressure-cooked sample. The results also showed an increase in the mineral composition of differently processed ragi and wheat. This increase in the mineral content may be attributed to reduction in phytic acid that might increase the bioavailability of minerals. Varying effect of different processes on the mineral compositions of maize kernels and groundnut seeds have been shown (Fubara et al., 2011).

The total carotenoid content was reduced in all the processed ragi samples when compared to their raw counterparts. Highest reduction of 94.8% was observed in PM ragi which may be attributed to loss in total lipid content at high temperatures in which carotenoids are soluble, while highest retention of 78.2% was in soaking followed by pressure cooking.

A significant reduction of 61.5% phytic acid in roasted ragi was observed. However, there is a report of 49.2 and 66.5% decrease in phytic acid content after germination and fermentation respectively (Mamiro et al., 2001). Due to antidiabetic, antioxidant and anticancerous activity of phytic acid, its partial retention after processing is beneficial (Thompson, 1993). A significant reduction in phytic acid content was also shown in fermented pearl millet cultivars (Hag et al., 2002). Generally, fermentation is known to cause a greater reduction in phytic acid than other antinutrients and this could be due to low pH during fermentation, which is considered to be optimum for phytase activity (Gunashree & Venkateswaran, 2008). However in the present study there was 35.2% reduction in phytic acid content of fermentation followed by germinated ragi, but highest reduction was in roasted sample. The total polyphenols reduced upto 65.8% after blanching. This may be attributed to leaching of soluble fractions into water. The total polyphenols in two cultivars of pearl millet was shown to reduce significantly with progress in fermentation period, which is due to microbial activity during fermentation process (Hag et al., 2002). Similarly reduction in the total extractable phenolics of boiled finger millet and red sorghum (Towo et al., 2003) and two varieties of raw cooked finger millet was shown (Chandrasekara et al., 2012). This is attributed to degradation of phenolics upon heat treatment or leaching into the endosperm to complex with proteins and other macromolecules thus making them less extractable. However, few studies have also shown increased total phenolics after hydrothermal treatment (Bryngelsson et al., 2002). This is attributed to release of phenolic compounds from esterified and insoluble bound form of the grain, suggesting the breakdown of cellular constituents by thermal application (Dewanto et al., 2002).

The present study showed 73.6% reduction in tannins soaking followed by pressure-cooked ragi. Among millets, finger millet is reported to contain high amounts of tannins ranging from 0.04 to 3.74% of catechin equivalents (Rao, 1994; Antony & Chandra, 1998). Rao and Prabhavathi (1982) have also shown reduced tannin content after soaking, roasting, boiling, germination and fermentation. Malting has been shown to decrease tannins up to 54% in brown finger millet (Rao, 1994) and phytic phosphorus up to 58 and 65% in brown and white finger millet respectively (Malleshi & Desikachar, 1986). Significant reduction of trypsin inhibitors up to 61.5% was found in roasting followed by pressure-cooked ragi. An insignificant reduction in trypsin inhibitors has been shown (Mbithi-Mwikya et al., 2000) in 3 days germinated finger millet.

The present study showed 51.8% reduction in the phytic acid content of roasted wheat. However, it is reported that phytic acid content can also reduce during baking (Faqir et al., 2002). A decline in phytic acid content of wheat has been shown during 72 h of germination, which is due to hydrolytic activity of phytase that is reported to be present in various plant foods (Hussain et al., 2011). Steve, (2012) has reported 31 and 20.6% reduction in germinated and fermented wheat respectively. A higher reduction of phytic acid was obtained in roasted wheat in the present investigation. There are sparse reports on the reduction of phytic acid in roasted cereals as made in the present investigation. Roasting, in addition to reducing phytic acids, also improves aroma, sensory, storage and nutritional quality of the product (Abdoulaye et al., 2011).

There was up to 87% reduction in the total polyphenols of roasted wheat and this was followed by fermented and blanched sample. Wheat bran has been shown to possess highest phenolics and antioxidant activity while endosperm has the lowest amount (Zhou et al., 2004). Tannin content of all processed wheat samples was reduced than raw sample, but highest reduction of 85.1% was observed in fermentation followed by germinated sample. This is in agreement with earlier reports (Hussain et al., 2011; Tabera et al., 1995). This reduction in tannin content in germinated seeds is attributed to the formation of hydrophobic associations of tannins with seed proteins and enzymes and may not be due to actual loss or degradation of tannins (Butler et al., 1984). However, increased tannin content has been shown after germination and fermentation of wheat (Steve, 2012). Trypsin inhibitors were also reduced in all the processed wheat samples than raw and significant reduction of 52.3% was in pressure-cooked sample. However, a slight increase in the TI was also shown after subjecting wheat to germination and fermentation (Steve, 2012).

Table.1 Nutritional composition of raw and processed ragi (*Eleusine coracana*)

Process	Total sugars	Crude protein	Total fat	Crude fiber	Ash	Moisture	Energy (K cal)
	%						
M (control)	74.7 ± 0.036	6.8 ± 0.01	1.8 ± 0.02	3.17 ± 0.02	2.0 ± 0.015	8 ± 0.083[g]	335.34
RM	68.4 ± 0.08[a]	4.38 ± 0.025[c]	1.4 ± 0.01[a]	2.02 ± 0.01[a]	1.8 ± 0.015[c]	2 ± 0.01[a]	307.76[a]
RPM	76.7 ± 0.13[c]	7.88 ± 0.01[b]	1.1 ± 0.01[a]	2.6 ± 0.01[c]	2.0 ± 0.005[c]	7 ± 0.052[c]	353.42[c]
BM	67.4 ± 0.1[a]	12.76 ± 0.02[b]	1.6 ± 0.015[c]	3.11 ± 0.005[c]	2.4 ± 0.01[b]	5 ± 0.03[a]	342.62[c]
PM	79.41 ± 0.11[b]	7.26 ± 0.01[b]	1.0 ± 0.01[a]	3.13 ± 0.011[c]	2.2 ± 0.01[c]	6 ± 0.005[c]	361.94[b]
SPM	72.5 ± 0.02[c]	12.26 ± 0.02[b]	1.3 ± 0.01[a]	3.13 ± 0.01[c]	2.4 ± 0.01[b]	6 ± 0.011[c]	359.0[b]
SM	71.2 ± 0.1[c]	3.1 ± 0.015[c]	1.3 ± 0.015[a]	3.08 ± 0.011[c]	2.2 ± 0.005[c]	4 ± 0.015[a]	351.7[c]
SFM	55.8 ± 0.09[a]	8.25 ± 0.03[b]	1.3 ± 0.025[a]	2.55 ± 0.015[c]	2.0 ± 0.01[c]	6 ± 0.02[c]	263.22[a]
SFGM	67.2 ± 0.25[a]	13.5 ± 0.01[b]	1.7 ± 0.02[c]	3.66 ± 0.005[b]	1.8 ± 0.01[c]	3 ± 0.02[a]	303.2[a]
SGKM	71.3 ± 0.04[c]	12.63 ± 0.01[b]	1.4 ± 0.01[a]	3.08 ± 0.005[c]	2.0 ± 0.064[c]	4 ± 0.015[a]	314.48[a]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

Table.2 Nutritional composition of raw and processed wheat (*Triticum sps*)

Process	Total sugars	Crude protein	Total fat	Crude fiber	Ash	Moisture	Energy (K cal)
			(%)				
M (control)	70.2 ± 0.021	11.18 ± 0.06	2.1 ± 0.01	2.08 ± 0.011	1.2 ± 0.057	6 ± 0.057	348.58[c]
RM	69.6 ± 0.02[c]	6.39 ± 0.05[a]	1.4 ± 0.015[a]	2.08 ± 0.02[c]	1.2 ± 0.058[c]	6 ± 0.058[c]	320.72[a]
RPM	76.3 ± 0.017[b]	10.38 ± 0.01[a]	2.0 ± 0.005[c]	1.6 ± 0.005[a]	1.6 ± 0.062[b]	8 ± 0.062[b]	367.92[b]
BM	63.5 ± 0.015[a]	11.18 ± 0.04[c]	1.1 ± 0.005[a]	2.08 ± 0.002[c]	1.4 ± 0.06[c]	6 ± 0.06[c]	312.78[a]
PM	75.7 ± 0.021[b]	10.6 ± 0.025[c]	1.8 ± 0.011[c]	2.11 ± 0.01[c]	1.8 ± 0.04[b]	7 ± 0.04[c]	365.62[b]
SPM	68.3 ± 0.005[c]	8.8 ± 0.023[d]	1.5 ± 0.01[a]	1.55 ± 0.035[a]	1.4 ± 0.053[c]	5 ± 0.053[c]	325.0[c]
SM	65.4 ± 0.01[a]	8.8 ± 0.015[a]	1.3 ± 0.015[a]	1.6 ± 0.011[a]	1.0 ± 0.046[c]	8 ± 0.046[b]	311.7[a]
SFM	63.6 ± 0.02[a]	11.8 ± 0.025[b]	0.8 ± 0.015[a]	1.03 ± 0.01[a]	2.0 ± 0.053[b]	5 ± 0.053[c]	310.86[a]
SFGM	78.3 ± 0.01[b]	10.98 ± 0.02[c]	1.2 ± 0.01[a]	1.52 ± 0.005[a]	1.2 ± 0.056[c]	5 ± 0.056[c]	370.96[b]
SGKM	80.0 ± 0.049[b]	11.88 ± 0.36[b]	1.3 ± 0.015[a]	1.47 ± 0.02[a]	1.3 ± 0.062[c]	4 ± 0.062[a]	382.16[b]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

Table.3 Mineral contents (mg/100g) of raw and processed ragi (*Eleusine coracana*)

Process	Calcium	Magnesium	Copper	Manganese	Iron	Zinc	Potassium	Sodium
M (control)	280.6	350	71	246	4.97	2.56[a]	5.34	0.83
RM	236.1[a]	438[b]	53[c]	224.7[c]	5.08[c]	1.55[a]	3.77[a]	0.80[c]
RPM	293.5[c]	788[b]	277[b]	219.0[c]	8.2[b]	1.95[a]	5.14[c]	1.40[b]
BM	295.2[c]	1310[b]	1837[b]	281.7[b]	16.8[b]	2.45[c]	6.65[b]	0.88[c]
PM	341.7[b]	1226[b]	343[b]	276.1[b]	5.80[b]	2.08[a]	4.06[a]	0.90[c]
SPM	343.3[b]	1576[b]	170[b]	247[c]	11.23[b]	2.58[c]	3.87[a]	1.25[b]
SM	318.5[b]	1226[b]	353[b]	270.8[b]	6.16[b]	2.68[c]	4.32[a]	0.68[a]
SFM	316.6[b]	525[b]	171[b]	260.1[c]	50.9[b]	2.25[c]	4.70[a]	1.24[b]
SFGM	327.6[b]	350[c]	68[c]	259.7[c]	51.3[b]	2.15[c]	4.15[a]	1.05[b]
SGKM	264[c]	263[a]	50[c]	236.0[c]	50.5[b]	2.0[a]	5.00[c]	1.30[b]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

Table.4 Mineral contents (mg/100g) of raw and processed wheat (*Triticum* sps)

Process	Calcium	Magnesium	Copper	Manganese	Iron	Zinc	Potassium	Sodium
M (control)	105.84	9.51	0.64	3.44	3.91	2.31	4.51	0.60
RM	106.64[c]	10.17[b]	0.50[c]	2.88[a]	3.71[c]	2.67[c]	6.2b[a]	1.22[b]
RPM	111.25[c]	8.05[c]	2.08[b]	4.10[b]	5.30[b]	3.36[b]	6.52[b]	1.41[b]
BM	107.44[c]	10.30[b]	2.65[b]	3.05[a]	4.25[c]	3.12[b]	3.68[a]	0.64[c]
PM	110.74[c]	16.07[b]	1.20[b]	3.70[b]	4.88[b]	3.78[b]	5.53[b]	1.07[b]
SPM	110.02[c]	13.33[b]	0.95[b]	2.70[a]	4.32[b]	2.74[b]	3.76[a]	0.83[c]
SM	107.40[c]	9.86[c]	1.28[b]	2.60[a]	3.90[c]	2.95[b]	4.06[a]	0.55[a]
SFM	156.71[b]	11.45[b]	0.40[a]	2.31[a]	5.52[b]	2.60[c]	2.84[a]	0.80[c]
SFGM	187.16[b]	9.20[c]	0.51[c]	0.40[a]	4.22[c]	3.70[b]	4.30[c]	0.96[b]
SGKM	126.78[b]	9.77[b]	0.36[a]	3.10[a]	4.33[b]	3.47[b]	3.97[a]	0.60[c]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

Table.5 Carotenoid content (μg/g) in raw and processed ragi (*Eleusine coracana*)

Process	Lutein	β-carotene	Total carotenoids
M (control)	0.33[a]	-	43.82
RM	0.01[a]	-	30.4c[a]
RPM	0.09[a]	-	18.16[a]
BM	0.06[a]	-	14.48[a]
PM	0.25[c]	-	2.30[a]
SPM	0.08[a]	-	34.27[c]
SM	0.02[a]	-	30.6[a]
SFM	0.08[a]	-	31.17[a]
SFGM	0.02[a]	-	16.43[a]
SGKM	0.10[a]	-	24.54[a]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

Table.6 Carotenoid content (μg/g) in raw and processed wheat (*Triticum sps*)

Process	Lutein	β-carotene	Total carotenoids
M (control)	4.27	4	68.7
RM	0.7[a]	3.1[c]	41.2[a]
RPM	0.45[a]	2.7[a]	60.29[c]
BM	0.07[a]	-	27.63[a]
PM	0.27[a]	1.8[a]	39.57[a]
SPM	0.35[a]	2.46[a]	32.81[a]
SM	0.18[a]	-	16.54[a]
SFM	0.08[a]	-	5.58[a]
SFGM	4.07[c]	-	61.7[c]
SGKM	3.55[c]	-	67.7[c]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

Table.7 Antinutritional factors of raw and processed ragi (*Eleusine coracana*)

Process	Phytic acid (mg/100g)	Total polyphenols (mg GAE/ 100g)	Tannins (mg CAE/ 100g)	Flavonoids (mg CAE/ 100g)	Trypsin Inhibitors (mg/g)
M (control)	685	298	18.75	23.68	102.6
RM	264[a]	185[a]	11.2[c]	22.5[c]	71.1[a]
RPM	533[c]	150[a]	4.045[a]	21.47[c]	39.5[a]
BM	369[a]	102[a]	6.05[a]	22.35[c]	47.4[a]
PM	584[c]	290[c]	4.95[a]	19.26[c]	100[c]
SPM	513[a]	195[a]	2.205[a]	20.44[c]	84.2[c]
SM	440[a]	203[a]	12.15[c]	14.26[a]	100[c]
SFM	464[a]	170[a]	8.45[a]	11.91[a]	78.95[a]
SFGM	444[a]	179[a]	6.45[a]	21.03[c]	52.6[a]
SGKM	477[a]	209[a]	7.15[a]	11.62[a]	94.7[c]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

Table.8 Antinutritional factors of raw and processed wheat

Process	Phytic acid (mg/100g)	Total polyphenols (mg GAE/ 100g)	Tannins (mg CAE/ 100g)	Flavonoids (mg CAE/ 100g)	Trypsin Inhibitors (mg/g)
M (control)	440	379	8.65	36.3	226.3
RM	212[a]	49[a]	3.68[a]	31.62[c]	136.8[a]
RPM	416[c]	127[a]	6.45[a]	25[a]	121.1[a]
BM	308[a]	68[a]	2.39[a]	35[c]	128.9[a]
PM	372[a]	149[a]	8.1[c]	35.15[c]	118.4[a]
SPM	263[a]	122[a]	4.23[a]	23.23[a]	150[a]
SM	339[a]	151[a]	6.25[a]	24.85[a]	134.2[a]
SFM	287[a]	58[a]	3.68[a]	26.76[a]	131.6[a]
SFGM	402[c]	124[a]	1.29[a]	33.38[c]	131.6[a]
SGKM	425[c]	94[a]	2.94[a]	17.79[a]	139.5[a]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

Table.9 Antioxidant activity of raw & processed ragi

Process	Radical Scavenging activity (IC_{50} in µg/ml)	Reducing power (OD_{700}) (5 µg GAE)
M (control)	0.74	0.875
RM	1.375[a]	0.703[c]
RPM	2.81[a]	0.494[a]
BM	3.77[a]	0.407[a]
PM	1.17[c]	0.826[c]
SPM	1.33[a]	0.743[c]
SM	1.3[a]	0.749[c]
SFM	1.81[a]	0.572[a]
SFGM	1.42[a]	0.579[a]
SGKM	1.21[c]	0.765[c]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

Table.10 Antioxidant activity of raw & processed wheat

Process	Radical Scavenging activity (IC_{50} in µg/ml)	Reducing power ((OD_{700})) (5 µg GAE)
M (control)	0.47	1.11
RM	3.09[a]	0.102[a]
RPM	0.84[a]	0.846[c]
BM	1.13[a]	0.367[a]
PM	0.59[c]	0.868[c]
SPM	0.99[a]	0.574[a]
SM	0.48[c]	1.064[c]
SFM	1.78[a]	0.318[a]
SFGM	0.968[a]	0.706[a]
SGKM	1.11[a]	0.507[a]

M- milling; RM- roasting & milling; RPM- roasting, pressure cooking & milling; BM- blanching & milling; PM- pressure cooking & milling; SPM- soaking, pressure cooking & milling; SM- soaking & milling; SFM- soaking, fermenting & milling; SFGM- soaking, fermenting, germinating & milling, SGKM- soaking, germinating, kilning & milling

All values are mean of triplicates. Results expressed on dry weight basis

[a] significantly decreased compared to control at the level of $p \leq 0.05$

[b] significantly increased compared to control at the level of $p \leq 0.05$

[c] statistically insignificant compared to control

The highest retention in radical scavenging and reducing power activities of soaked wheat sample may be due to highest total polyphenolics, since the % DPPH inhibition is directly correlated to total polyphenolics (Alothman et al., 2009). An increased radical scavenging and reducing power activity has been shown in roasted little millet (Pradeep & Manisha, 2011).

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