ASSESSMENT OF THE NUTRITIONAL QUALITY OF SORTEX® REJECTED RICE AS A FEED RESOURCE FOR MONOGASTRIC ANIMALS: PHYSICAL CHARACTERISTICS, CHEMICAL COMPOSITION AND ENERGY VALUE

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ABSTRACT
Sortex® rejected rice (SRR) was investigated for its nutritional quality as an alternative feedstuff to replace maize in monogastric animal diets. Sortex rejected rice meal was characterized with respect to physical composition, proximate, energy, fibre, mineral and amino acid profile. The physical analysis indicated that SRR contained 58% broken rice, 34% full grain rice, 4% paddy rice, 3% soil and 1% other plant seeds. The dry matter, organic matter, crude protein, ether extract, crude fibre, ash, nitrogen-free extractive and metabolizable energy contents were: 899.9 g kg^{-1}DM, 888.2 g kg^{-1}DM,118.6 g kg^{-1}DM, 100.2 g kg^{-1}DM, 26.3.g kg^{-1}DM, 11.7 g kg^{-1}DM, 641.5 g kg^{-1}DM, and 14.68 MJ kg^{-1}, respectively. The contents of NDF, ADF, hemicellulose and AIA were, in g (kg^{-1}DM): 9.36, 8.83, 0.54 and 16.8, respectively. SRR was high in its contents of mineral elements such as calcium, phosphorus, potassium and magnesium and therefore can serve as a valuable source of minerals for animals. In comparison with maize, SRR contained more protein, ether extract, fibre, AIA, calcium, potassium, phosphorus, magnesium and metabolizable energy but less of nitrogen-free extractive, ash, NDF, ADF and mineral elements, such as zinc, manganese, copper and iron. Based on the results obtained with the by-product tested in this study, SRR has potential as an alternative feedstuff for animals especially if contaminants, such as other plant seeds and soil particles could be eliminated. Growth trials are recommended with monogastric animals, such as poultry and pigs to evaluate the replacement value of SRR when incorporated into the diets of these farm animals.

Keywords: *Sortex rejected rice, physical characteristics, chemical composition, energy value*

INTRODUCTION
Cereal demands for direct human use is expected to increase as more than half of the human race is undernourished and the world population is still increasing. Also, increasing demand for grains for biofuel production is driving up food and feed prices, resulting in escalating prices for meat, dairy and eggs (von Braun, 2007; Akbar *et al.*, 2018). Feed cost is the largest single item for livestock and poultry production accounting for 60 to 70% of the total cost of production (Lawrence *et al.,* 2008; Ashour *et al*., 2015). The cost of feeding has been reported to represent more than 50% of the total cost of pig production (Noblet and Perez, 1993) with that of poultry production ranging between 60 and 80% (Adesehinwa, 2007); with the energy component constituting the greatest portion.

Maize has historically been the dominant main source of energy in poultry diets (Sittiya and Yamauchi, 2014; Dei, 2017). As animal production systems based on high grain and high protein diets become unsustainable, researchers are seeking alternative energy sources for poultry and pigs primarily to reduce costs of diets by taking advantage of the large number of co-products that are generated from the food and other industries (Rhule *et al*., 2007; Donkoh and Attoh-Kotoku, 2009; Donkoh and Zanu, 2010; Zijlstra and Beltranena, 2013; Woyengo *et al.*, 2014).

Sortex rejected rice (SRR), a co-product of the industrial processing of paddy rice to produce polished rice, is one of the by-products that could potentially serve as an alternative energy feedstuff in non-ruminant diets. The Sortex is a machine used to ensure that in the de-husking and polishing process, the resultant rice grains are of even size and colour, and devoid of any contaminants. The Sortex machine isolates and successfully eliminates imperfections in the final rice grains and removes all unfamiliar materials such as, bad rice, dark rice, half-husked rice, stones and undesirable foreign seeds. Rice feeding has been reported to protect pigs against bacterial infections (Mathews *et al*., 1999; Pluske *et al*., 2003) and improves nutrient digestibility, feed intake and performance with respect to maize feeding (Mateos *et al*., 2007). Feeding rice instead of maize has also been reported to increase digestibility and improved the structure of the ileal mucosa of pigs (Vicente *et al*., 2009). The aim of the present study was to determine the nutrient quality of SRR available in Ghana and assess its potential as feed ingredient for poultry in terms of chemical composition and energy value.

MATERIALS AND METHODS

Source of Sortex rejected rice

A batch of Sortex rejected rice (SRR) (*Oryza sativa* L., Japonica) was obtained from a commercial rice processing company (Wienco (GH) Limited, Tema, Ghana) as a by-product from the processing of paddy rice into Sortex rice, which is a commodity traders' shorthand for referring to a category of rice which is generally regarded as being of higher value than standardized rice. For physical and chemical analysis, samples of SRR were randomly taken from 20 bags. The samples were thoroughly mixed and 2 kg taken for various analyses. One kg of the mixed sample was weighed for physical analysis, and the other 1 kg of the sample was dried to a moisture content of about 10%, ground through a hammer mill (1 mm screen) and stored in polythene containers until used for chemical analysis.

Physical analysis

One (1) kg of the mixed SRR was divided into five equal lots of 200 g each. Each of the 200 g SRR sample was poured on to a flat surface and the individual components of the SRR (i.e. full grain rice, paddy rice, broken rice, seeds of other plants and soil particles) were separated, weighed and expressed as percentages of the total weight.

Chemical analysis

Analyses for crude protein, crude fibre, ether extract, ash and dry matter contents were done in triplicates, generally following the procedures by AOAC (2016). Organic matter (OM) was calculated by subtracting the ash from the DM content. Nitrogen free extract was estimated by difference (DM-CP-EE-CF-Ash). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to the methods of Van Soest *et al.* (1991) and hemicellulose was estimated as difference between NDF and ADF. Mineral analysis was carried out using standard AOAC method (AOAC, 2016) and the acid-insoluble ash content of SRR was determined gravimetrically after drying, ashing, boiling of ash in hydrochloric acid, filtering and washing of the hot hydrosylate, and re-ashing (Van Keulen and Young, 1977). The amino acid composition of SRR samples were determined on duplicate 6 mg samples using high-performance liquid chromatography as outlined by the AOAC (2016) standard procedures. The metabolizable energy of the samples of SRR was calculated from its chemical composition using the equation of Pauzenga (1985): ME (kcal kg^{-1}) = (37 x % protein) + (81.8 x % fat) + (35 x % nitrogen free extract)

RESULTS AND DISCUSSION

Physical analysis

The physical analysis as presented in Table 1 indicated that SRR comprised 58% broken rice, 34% full grain rice, 4% paddy rice, 3% soil material and 1% other plant seeds. The objective of the rice milling systems is to remove the husk and the bran layer of the rice kernel, which makes the rice edible and free from impurities and foreign matter that consists of stones, straw, weed seeds and soil (Bodie *et al*., 2019).

Table 1: Physical composition of Sortex rejected rice

Component	%
Broken rice	58.0
Full grain	34.0
Paddy rice	4.0
Soil particles	3.0
Other plants seeds	1.0
Total	**100.0**

Depending on the requirements of the customer, the rice should have the minimum of broken kernels possible (typically 12 – 15%) (Siebenmorgen *et al*., 2011; Dhankhar, 2014; IRRI, 2016). The soil material and the other plant seeds, making up a total of 4% of the total composition of the SRR, as observed in this study, might be considered as contaminants. The physical characteristics of a feed have a direct effect on the way it is digested (Kingsly *et al*., 2010). Ingestion of soil or grit could lead to accumulation of siliceous components in the digestive tract (Sales and Janssens, 2003). Rymer (2000) also outlined the consequences of consumption of soil contaminated feed and its possible absorption from the gut and its associated risk. Soil and dust in feed should therefore, as much as possible, be eliminated.

Chemical analysis

Table 2 shows the chemical composition of the SRR evaluated in this study. Data on maize is also provided for the purposes of comparison. The SRR evaluated in this study had a dry matter content of 899.9 g kg^{-1} DM with a corresponding moisture content of 100.1 g kg^{-1} DM. Moisture content has been established as an important indicator of shelf life for foods and feeds (Isengard, 2001; Rothman *et al*., 2012). The moisture content of feeds is directly related to water activity; the higher the water activity, the more susceptible the feed will be to interactions with microbes and its environment. Consequently, the low moisture content of 100.1 g kg^{-1} DM, will inhibit the growth and development of micro-organisms and the SRR will have long shelf life. The determined crude protein content of 118.6 g kg^{-1} DM for SRR as obtained in this study is higher than that of maize as reported by various authors. For example, NRC (2012) earlier reported of a protein content of 89.2 g kg^{-1} DM for maize while Stein *et al*. (2016) also reported of protein content of 81.0g kg^{-1} DM for maize. It is also worth noting that, the determined crude protein level for SRR as obtained in this study is higher than that of polished rice (81.0 g kg^{-1}DM) as reported by Stein *et al*. (2016).

The crude fibre content of SRR (26.3 g kg^{-1} DM) obtained in this study was higher than that of maize (22.0 g kg^{-1} DM) as reported by NRC (2012). The determined crude fibre level is lower than the total dietary fibre value of 95.0g kg^{-1} DM for maize as reported by Stein *et al.* (2016). The crude fibre fractions obtained in this study for SRR were as follows: neutral detergent fibre (9.36 g kg^{-1} DM), acid detergent fibre (8.83 g kg^{-1} DM), and hemicellulose (0.54 g kg $^{-1}$ DM). The corresponding values obtained by Stein *et al*. (2016) for maize were 102.7 g kg^{-1} DM, 29.0 g kg^{-1} DM and 73.0 g kg^{-1} DM for NDF, ADF and hemicellulose, respectively. The corresponding values reported for maize by NRC (2012) are 96 g kg^{-1} DM, 28 g kg^{-1} DM and 68 g kg^{-1} DM, respectively. The NDF and ADF levels obtained in the present study for SRR are lower than the crude fibre which is mostly cellulose, whereas the ADF consists of cellulose and lignin. The NDF fraction, which represents the slower digestible fibrous portion, corresponds mainly to the sum of cellulose, hemicelluloses and lignin. Neutral detergent fibre measures all the fibrous constituents in feeds and is inversely related to the energy content (Mertens, 1985; Anderson, 2016). Fibre, as a nutrient, is harder to digest by monogastric animals than NFE and determines dietary nutritive value because of its influence on the proportion of chemically available nutrients which can be utilized by the animals. This is a result of low digestibility of fibres. This might have influenced the energy content of the SRR, which is higher than the metabolizable energy content of maize. The energy content obtained in the present study (14.8 MJ kg^{-1}) for SRR is higher than the value (14.30 MJ kg^{-1}) reported by NRC (2012) for maize. The energy value obtained in this study makes SRR a potential energy feedstuff.

The results of the mineral elements assayed in this study are also presented in Table 2. The ash content of the SRR, which is an indication of the mineral element concentration in a feedstuff, was lower than the values reported for maize. Stein *et al*. (2016) reported slightly higher concentration of ash (14.0 g kg^{-1} DM) in the sample of maize assayed in their study, while NRC (2012) reported similar value for maize. Chemical analysis of the SRR sample indicated it contained 16.8 g kg^{-1} DM of acid-insoluble ash.

Acid-insoluble ash indicates siliceous impurities and consists of indigestible mineral components, primarily silica and silicates (Sales and Janssens, 2003) and is often higher in paddy rice (Satter *et al*., 2014). Silica is a mineral that is needed in small amounts and excessive intake causes lung damage (Richards, 2003). The levels of minerals obtained in this study for SRR, particularly the major or macro-minerals, are all higher than the values reported by NRC (2012) for maize except for the trace or micro-minerals, such as sodium, zinc, manganese, copper and iron which were lower. Macro-mineral elements, such as calcium and phosphorus, are important nutrients in animal diet formulations (Li *et al*., 2017). They form the components of bodily structures and fluids (electrolytes) and are also involved in the biochemical reactions which occur in the animal body. The results show that compared with maize, SRR may be less deficient in minerals and can thus serve as valuable source of mineral elements for animals.

Table 2: Chemical composition of Sortex rejected rice and maize

Component	SRR[a]	Maize[b]	SRR: maize
Proximate analysis (g kg^{-1}DM)			
Dry matter	899.9	887.5	1.01
Organic matte	888.2	868.5	1.02
Crude protein	118.6	89.2	1.33
Ether extract	100.2	44.8	2.24
Crude fibre	26.3	19.3	1.36
Ash	11.7	19.0	0.62
Nitrogen free extractive	643.1	827.7	0.78
Fibre components (g kg^{-1}DM)			
Neutral detergent fibre	9.36	96.0	0.10
Acid detergent fibre	8.83	28.0	0.32
Hemicellulose	0.54	68.0	0.008
Acid insoluble ash	16.80	0.60	28.0
Mineral elements			
Calcium (g kg^{-1}DM)	5.7	0.3	19.0
Phosphorus (g kg^{-1}DM)	2.9	2.8	1.04
Potassium (g kg^{-1}DM)	3.61	3.3	1.09
Magnesium (g kg^{-1}DM)	4.58	1.2	3.82
Sodium (g kg^{-1}DM)	0.18	0.2	0.90
Zinc (mg kg^{-1})	0.273	180	0.002
Manganese (mg kg^{-1})	0.149	70	0.002
Copper (mg kg^{-1})	0.811	30	0.03
Iron (mg kg^{-1})	0.991	290	0.003
Metabolizable energy MJ kg^{-1})[c]			

[a] *Values based on triplicate samples*
[b] *Values reported by NRC (2012), Stein et al. (2016)) and INRAE CIRAD AFZ (2017)*
[c] *Estimated according to the formula of Pauzenga (1985)*

Table 3: Amino acid composition of SRR and maize (g kg^{-1}DM)

Amino Acid	SRR[a]	Maize[b]	SRR Maize
Indispensable amino acids			
Arginine	7.60	3.80	2.00
Histidine	2.25	2.40	0.94
Isoleucine	4.05	2.80	1.40
Leucine	8.01	9.60	1.21
Lysine	3.56	2.60	1.36
Methionine	2.48	1.70	1.45
Phenylalanine	5.36	3.90	1.37
Threonine	3.37	2.90	1.16
Tryptophan	1.25	0.60	2.08
Valine	5.53	3.80	1.73
Dispensable amino acids			
Alanine	5.46	6.00	0.91
Aspartic acid	9.05	5.40	1.67
Glutamic acid	16.38	14.80	1.10
Glycine	4.17	3.20	1.30
Proline	4.75	6.90	0.68
Seine	4.93	3.80	1.29
Tyrosine	3.20	2.60	1.23

[a]*Values based on duplicate samples*
[b]*Values reported by NRC (2012) and Stein et al. (2016))*

The gross amino acid compositions of SRR in comparison with that of maize are presented in Table 3. The dietary provision of amino acids in correct amounts and proportions determines the adequacy of a dietary ingredient (NRC, 2012). Amino acids, normally supplied by dietary protein, are required for maintenance, growth, reproduction and other functions (Cromwell, 2015).

The gross indispensable amino acids contents of SRR ranged from 1.25 g kg^{-1} DM for tryptophan to 8.01 g kg^{-1} DM for leucine, while that of maize ranged from 0.60 g kg^{-1} DM for tryptophan to 9.60 g kg^{-1} DM for leucine. With the exception of the leucine and histidine contents, all the indispensable amino acids contents of SRR evaluated in this study, were higher than those of maize. The dispensable amino acids contents of SRR are also higher than those of maize, with the exception of the gross proline and alanine. Amino acids in the protein of both SRR (16.38 g kg^{-1} DM) and maize (14.80 g kg^{-1} DM) were generally high in glutamic acid. The values for aspartic were also generally high. Glutamic acid is considered to be a conditionally essential amino in some species (Lacey and Wilmore, 1990), because it prevents intestinal atrophy under certain conditions.

The results of the chemical analysis of the sample of SRR used in this study indicated that it has the potential to supply energy, protein and mineral elements in animal feeding systems. According to Tavares *et al*. (2016), by-products generated during rice processing including broken rice, are high quality products having metabolizable energy and protein levels similar to maize, and lysine and methionine levels slightly higher than maize, besides having good amount of starch (Corado *et al*., 2017). Based on the results obtained with the by-product tested in this study, it is concluded that SRR is a suitable alternative feed source to be investigated in greater detail.

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