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Comparative analysis of non-destructive and destructive measurements of some proximate compositions of wheat for confectionery and pasta production

Chukwu O.[1] and Ismail Abdulwahab Durojaiye[2]*

[1]Department of Agricultural and Bioresources Engineering, Federal University of Technology, PMB 65, Minna, Nigeria.
[2]Department of Agricultural and Bio-resource Engineering, Abubakar Tafawa Balewa University, PMB 0248, Bauchi, Nigeria.

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ABSTRACT

In this research work, comparative evaluations of proximate compositions of wheat (*Triticum aestivum*) using non-destructive and destructive methods were determined. DA7200 near infra-red (NIR) spectrophotometer was used to measure some proximate compositions of wheat as a non-destructive method while the standardized conventional method by Association of Official Analytical Chemists (AOAC) food analysis scheme was used for the destructive approach. A randomized block design of 6 (Quality attributes) × 2 (Laboratory method of analysis) × 3 (Replicates) making a total of 36 samples used for the experiment. SPSS 20.0 statistical package was used to determine significant levels ($P < 0.05$) for the values obtained from both methods using analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT). Non-destructive measurement had significantly higher values of moisture content for wheat 11.07 ± 0.03%, crude fibre 3.00 ± 0.00% and carbohydrate 71.80 ± 0.35% over the destructive measurement having 9.50 ± 0.10%, 2.67 ± 0.07% and 67.28 ± 0.39%, respectively. Near infra-red techniques for obtaining the proximate compositions in wheat was therefore found to be more economical and faster without destroying the actual proximate compositions of the grains, therefore recommended for used over the conventional method.

Keywords: Destructive, non-destructive, proximate compositions, wheat, DA7200 near infra-red (NIR) multipurpose analyzer.

*Corresponding author. E-mail: wahabibnismail2008@gmail.com.

INTRODUCTION

Wheat (*Triticum* spp.) is a grass that is cultivated worldwide. Globally, it is the most important human food grain and ranks second in total production as a cereal crop behind maize, the third being rice (Adams et al., 2002). Wheat grain is a staple food used to make flour for leavened, flat and steamed breads, cookies, cakes, pasta, spaghetti, macaroni, noodles, couscous and for fermentation to make beer, alcohol, vodka or biofuel (Adams et al., 2002). The husk of the grain, separated when milling white flour, is bran (Barro et al., 1997). Wheat is planted to a limited extent as a forage crop for livestock and the straw can be used as fodder for livestock or as a construction material for roofing thatch (Beta et al., 2005; Blenchl et al., 2007).

Wheat is considered to be good source of protein, minerals, B-group vitamins and dietary fibre, that is, an excellent health-building food. Thus, it has become the principal cereal, being more widely used for the making of bread than any other cereal because of the quality and quantity of its characteristic protein called gluten. Gluten makes bread dough stick together and gives it the ability to retain gas. Wheat has several medicinal virtues, some of which include starch and gluten having the ability to provide heat and energy, the inner bran coats, phosphates and other mineral salts, the outer bran which is the much-needed roughage, is known to be indigestible portion that helps easy movement of bowels, the germ, vitamins B and E and protein of wheat help to build and repair muscular tissue. The wheat germ, which is removed in the process of refining, is also rich in essential vitamin E, the lack of which can lead to heart disease. The loss of vitamins and minerals in the refined wheat flour has led to widespread prevalence of constipation and other digestive disturbances and nutritional disorders. The whole wheat, which includes bran and wheat germ, therefore, provides protection against diseases such as constipation, ischaemic, heart disease and disease of the colon called diverticulum, appendicitis, obesity and diabetes (Kumar et al., 2011).

Cereal grains such as wheat, maize, oats, barley, millet, sorghum, acha and rye are best for human nutrition when put into the form of flour, meal, pastas or flakes. The seeds of these grains consist of three parts: the germ containing oil (Vitamin E), the endosperm (interior part containing the starch) and the bran which is the protective covering containing fibre. The bran portion also called milled feed is sold mainly as an ingredient for cattle and sheep feeds but has become important as fibre in healthy diet. The amount of germ in cereal grains varies from less than 2% in wheat to more than 10% in corn and because of high oil content, the germ is often roasted and sold vacuum-packed to prevent its becoming rancid. The germ oil can be pressed out in the milling industries and sold as cooking oil (David et al., 2004). Foods containing cereal flours have been very important to human nutritional needs since ancient time. In developing countries, most cereal flours are enriched with Vitamin B1, Vitamin B2, niacin and iron. Vitamin D and calcium are also added to flours for use in areas where flour is a primary nutritional source.

High quality standards and the necessity for shelf life determination have increased the need for simple and quick evaluation of the internal properties of agricultural produce. This kind of evaluation preferably makes use of non-destructive devices that sense the products quality attributes such as firmness or flavour (Galili and De-Baerdamaeker, 1996). For firmness, several sensors have reached the commercial market. These sensors are based on impact analysis or vibrations (acoustics). Although those sensors have proven their merit in laboratory scale experiments, however critical mass still needs to be convinced. For many years people have been used to older, standard techniques such as Magness Taylor (MT) type of devices; they have reservation in accepting the newly developed sensors that express firmness in different units on different scales.

Non-destructive measurement refers to measurement performed using specialized equipment without causing any adverse effect or damage on the product on which the measurement is carried out. Non-destructive testing (NDT) is a wide group of analytical techniques used in science and industry to evaluate the properties of a material, component or system without causing damage (Cartz, 1995).

The terms Non-destructive examination (NDE), Non-destructive inspection (NDI) and Non-destructive evaluation (NDE) are also commonly used to describe this technology (Charles, 2003). Because NDT does not permanently alter the article being inspected, it is a highly-valuable technique that can save both money and time in product evaluation, troubleshooting and research. Common NDT methods include ultrasonic, magnetic-particle, liquid penetrant, radiographic, spectrophotometer [Near Infrared (NIR), Mid-Infrared (MI) or Far-Infrared (FI) Spectroscopy], remote visual inspection (RVI), eddy-current testing and low coherence interferometry (Dufour et al., 2004; Losert, 2009). NDT is a commonly-used tool in agricultural engineering, forensic engineering, mechanical engineering, electrical engineering, civil engineering, systems engineering, aeronautical engineering, medicine and art (Cartz, 1995).

Near infra-red spectroscopy provides an alternative, non-destructive technology for measuring constituents of biological materials. Organic molecules have specific absorption patterns in the near infra-red region that can report the chemical composition of the material being analyzed (Williams and Norris, 2001). Near infra-red spectra can be collected either from the reflectance (NIR) of a sample or the transmittance (NIT) through a sample (Delwiche, 1995).

Near Infra-red Spectrophotometer (NIRS) is routinely used in agriculture, pharmaceuticals, and astronomy for the analysis of food stuffs, drugs and many research analyses. The method has been broadly accepted and is widely used in quality assessment of foods, beverages and researches. The method is relatively inexpensive, rapid, preserves the sample and is able to measure several constituents concurrently. Current food and beverage applications of NIRS are dominated by proximate quality assessment and research focused on this aspect of near infra-red analysis is very active. Interest in the application of near infra-red spectrophotometer to microbiological research and analysis has grown in recent times. However, the use of NIRS as a tool for monitoring, ecological and physiological research remains underdeveloped. Research investigating its use in these and other microbiological monitoring functions is required and would provide a valuable, cost effective addition to proximate systems already in place within many food industry (Rolf, 2009).

Durum wheat kernel is sometimes called the wheat berry. The kernel is the seed from which the wheat plant grows. Each tiny seed contains three distinct parts that are separated during the milling process to produce flour. The endosperm is about 83% of the kernel weight and the source of white flour, the endosperm contains the greatest share of protein, carbohydrates and iron as well as the major B-vitamins, such as *riboflavin*, niacin and *thiamine*. It is also a source of soluble fibre. The bran flour is about 14% of the kernels weight (Brink et al., 2006).

Bread wheat (hard red spring type) was reported to constitute per 100 g edible protion: 1377 kJ energy, 15.4 g of protein, 1.9 g of fat, 68.0 g of carbohydrate, 12.2 g of dietary fibre, 25 mg of calcium, 124 mg magnessium, 332 mg of phosphorous, 3.6 mg of iron, 2.5 mg of zinc, 0.50 mg of thiamine, 0.11 mg of riboflavin, 5.7 mg niacin, 0.34 mg of vitamin $B_{6,}$ 43 µg of folate and 0 mg of ascobic acid amongst others [15].

The first type of wheat cultivated was *einkorn*, diploid wheat containing seven chromosome pairs. A 28-chromosome tetraploid wheat known as *emmer* later evolved and was cultivated extensively in the Middle East. *Durum* wheat, which is used today to make pastry products, is also tetraploid. The wheat used today to make dough and better-based products is hexaploid, having six sets of each of the seven basic chromosomes. With respect to biological classification, three species of wheat are commonly grown. The first, *Triticum aestivum* forms the classes of hard red winter, hard red spring, soft red winter, hard white, and soft white. *Triticum compactum* includes club wheats. The third species is *T. durum,* which includes the durum and red durum wheat classes. Three sets of terms are used to describe most modern wheat types. The first, hard and soft, relate to the hardness of the kernel. Hard wheat requires more energy to mill than the soft wheat, as each individual kernel requires more force to crush it. The second, red and white, relates to the presence or absence of a reddish pigment in the outer layers of the wheat kernel. A visual examination is all that is required to differentiate these two types of wheat. The third, winter and spring, generally describes the growth habit of the wheat (Atwell, 2001).

Adams et al. (2002) in a study reported that globally, there is no doubt that the number of people who rely on wheat for a substantial part of their diet amounts to several billions. Therefore, the nutritional importance of wheat proteins should not be underestimated, particularly in less developed countries where bread, noodles and other products (e.g. burger and couscous) may provide a substantial proportion of the diet. Wheat provides more than 55% of carbohydrate and 20% of the food calories. Wheat contains carbohydrate 78.10%, protein 14.70%, fat 2.10%, minerals 2.10% and considerable proportions of vitamins (thiamine and vitamin-B) and minerals (zinc, iron). Wheat is also a good source of trace minerals like selenium and magnesium which are nutrients essential to good health (Alan et al., 2000). Wheat grain precisely known as caryopsis consists of the pericarp or fruit and the true seed. In the endosperm of the seed, about 72% of the protein is stored, which forms 8 to 15% of total protein per grain weight. Wheat grains are also rich in pantothenic acid, riboflavin and some minerals and sugars. The bran, which consists of pericarp testa and aleurone, is also a dietary source for fibre, potassium, phosphorus, magnesium, calcium and niacin in small quantities (Topping, 2007).

The kernel of wheat is a storehouse of nutrients essential to the human diet. Endosperm is about 83% of the kernel weight; it is also the source of white flour. The endosperm contains the greatest share of the protein in the whole kernel, carbohydrates, iron as well as many B-complex vitamins, such as riboflavin, niacin and thiamine. Bran is about 14.5% of the kernel weight (Drankham et al., 2003; Uauy et al., 2006). Bran is included in whole-wheat flour and is available separately, of which the nutrients in whole wheat also contains a small amount of protein, larger quantities of the B-complex vitamins listed above, trace minerals, and indigestible cellulose material called dietary flour. Wheat germ is the embryo of the wheat kernel. The germ or embryo of the wheat is relatively rich in protein, fat and several of the B-vitamins (Adams et al., 2002). The outer layers of the endosperm and the aleurone contain a higher concentration of protein, vitamins and phytic acid than the inner endosperm. The inner endosperm contains most of the starch and protein in the grain. It is separated from wheat being milled for flour.

Wheat germ is sodium and cholesterol free and dense in nutrients. It is rich in vitamin E, magnesium, pantothenic acid, phosphorus, thiamine, niacin and zinc. It is also a source of coenzyme Q10 (ubiquinone) and PABA (para-aminobenzoic acid) (Shewry, 2009). Wheat germ is also high in fibre and contains approximately 1 gramme of fibre per tablespoon. A diet high in fibre can be useful in regulating bowel function (that is, reducing constipation) and may be recommended for patients at risk for colon disease, heart disease and diabetes (Shewry, 2009).

However, because of the ever growing food industry and its demand for high quality of agricultural produce, there is need to come up with advanced and accurate techniques of determining the quality of food substance before distribution. To address this problem, DA7200 NIR spectrophotometer was found to be a very useful method of measuring large sample of grains on the factory floor within a short period time since it is rapid, economical and non-destructive. Therefore, the thrust of this study is to comparatively evaluate non-destructive and destructive measurements of proximate compositions of wheat (*T. aestivum*) necessary for the production of confectionery and pasta during postharvest handling on the factory floor. Non-destructive method will save time and energy.

MATERIALS AND METHODS

Commercially available wheat (*T. aestivum*) sample used for the analysis was procured from Apata Main Market, Ibadan, Oyo State, Nigeria. The cultivated grain variety of wheat sample was placed in polyethylene bag under ambient temperature and was used as they were purchased. Both the destructive and non-destructive measurements were conducted in Jaagee Nigeria Limited Laboratory in Ibadan under the same condition. However, all the reagents used for the laboratory analysis were of analytical grade and most of the equipment used for the analysis are sophisticated and automated. Some of the reagents used include Acetone, 1.2% H_2SO_4 solution (Tetraoxosulphate (VI) acid), 1.25% NaOH solution (sodium hydroxide solution), selenium catalyst, Petroleum ether 60 to 80°C, Copper catalyst, 40% NaOH solution (used for protein digestion and steam distillation), 0.1 g of Methyl red indicator ($C_{15}H_{15}N_3O_2$), 0.1 g of Bromocresol green indicator ($C_{21}H_{14}Br_4O_5S$), 4% Boric acid (H_3BO_3), Receiver solution, 0.1 N HCl and Distilled water amongst others. However, AOAC laboratory scheme was systematically followed for laboratory test.

Determination of proximate compositions of wheat (destructive and non-destructive methods)

Diode array near infrared spectrophotometer (DA7200 NIR multipurpose analyzer by Perten Instrument Company in Sweden) operation manual standardized by association of official analytical chemists (AOAC, 2006) was followed to carry out non-destructive measurements on the cereal grain to determine it proximate compositions. This involve measurement of about 20 to 30 g of the sample in the plate provided for the equipment, placing the sample container under the DA7200 NIR spectrophotometer and press the analyze botton. The NIR ray scan through the sample as it rotate within it confirment and immediately, the result of the proximate compositions was displayed on the DA7000 screen under 1 to 2 min. For the destructive approach, proximate compositions determination were assayed as described by association of official analytical chemists food analysis scheme for the determination of proximate compositions of cereal grains, all the reagents used for the laboratory analysis were all of analytical grade and most of the equipment used for the analysis are sophisticated, automated and are supplied by Foss Company (Sweden). Each analysis was carried out in triplicates.

A randomized block design of 6 (Quality attributes) × 2 (Laboratory methods of analyses) × 3 (Replicates) making a total of 36 samples used for the experiment.

Statistical analysis

Data obtained in this research work were statistically analyzed to determine the level of significance in the parameters evaluated when the two methods were applied. Proximate compositions analysis was replicated (n = 3) in both methods. Results presented are mean values of each determination ± standard error mean (SEM). Analysis of variance was performed by one-way ANOVA procedures (SPSS 20.0 for Windows). Comparisons between the mean values obtained in both methods were determined by Duncan's Multiple Range Test and the significant was defined at $P < 0.05$.

This paper brought awareness to food processing industries on the importance of DA7200 NIR spectrophotometer. It is obivious that the sample used for the non-destructive experiment can be utilized for further food processing and other purposes without discarding the sample. Therefore this method is economical, fast and save time compared to the previousely available method, which involved crushing the sample, addition of chemical reagents in the samples analyzed and then finally, the sample analyzed becomes wasted. This lead to losses of food along the food chain.

RESULTS AND DISCUSSIONS

The results of this research work (Table 1) and the error bar indicating the level of significant in the values (Figure 1) shows that there were significant differences in moisture contents of wheat cereal grain used for the determination of the proximate compositions when both destructive and non-destructive approaches were applied ($P < 0.05$). The comparison of the result obtained, revealed that non-destructive method quantified higher significant values in the moisture content of wheat 11.07 ± 0.03% over the moisture content records for wheat 9.50 ± 0.10% when the destructive approach was applied. The trend of this result was observed to be low when compared with the previous findings for wheat 12.8 ± 0.00% (Atwell, 2001). This is an indication that non-destructive method is more advantageous over the destructive method in terms of accuracy and rapidity in moisture content determination for cereal grains, hence, the shelf-life of wheat variety used will be prolong in term of storability as water supports growth of microorganisms that are responsible for food spoilage. Variations in the moisture content could be as a result of varietal differences in the wheat sample used for the experiment.

The results of this analysis indicate that there was no significant difference ($P < 0.05$) in crude protein contents of wheat when values obtained from both methods were compared with each other 13.03 ± 0.12% for the destructive and 12.80 ± 0.15% for the non-destructive method. In both methods, the obtained crude protein contents is significantly lower when compared with the previous findings on wheat 15.4 ± 00%, varietal differences and some anatomical variation could be the reason for the observed difference. Nutritionally, protein is an essential components required by the human body. However, this implies that wheat could be used in the formulation of protein-rich carbonated beverages in food preparations where maximum solubility of protein is

Table 1. Some proximate compositions of wheat using destructive and non-destructive methods.

Parameter	Sample	Method used		Remark
		Destructive	Non-destructive	
Moisture content (%)	Wheat	9.50 ± 0.10^b	11.07 ± 0.03^a	∗
Crude protein (%)	Wheat	13.03 ± 0.12^a	12.80 ± 0.15^a	N/S
Crude fat (%)	Wheat	3.11 ± 0.41^a	N/A	-
Crude fibre (%)	Wheat	2.67 ± 0.07^b	3.00 ± 0.00^a	∗
Ash (%)	Wheat	4.41 ± 0.01^a	1.70 ± 0.00^b	∗
Carbohydrate (%)	Wheat	67.28 ± 0.39^b	71.80 ± 0.35^a	∗

∗ = Significant different ($P \leq 0.05$), - = Not Comparable, NS = Not significantly different ($P \geq 0.05$), N/A = Not Available. Values on the same column for each parameter with different superscript are significantly different ($P \leq 0.05$) while those with the same superscript are not significantly different ($P \geq 0.05$) as assessed by Duncan's Multiple Range Test.

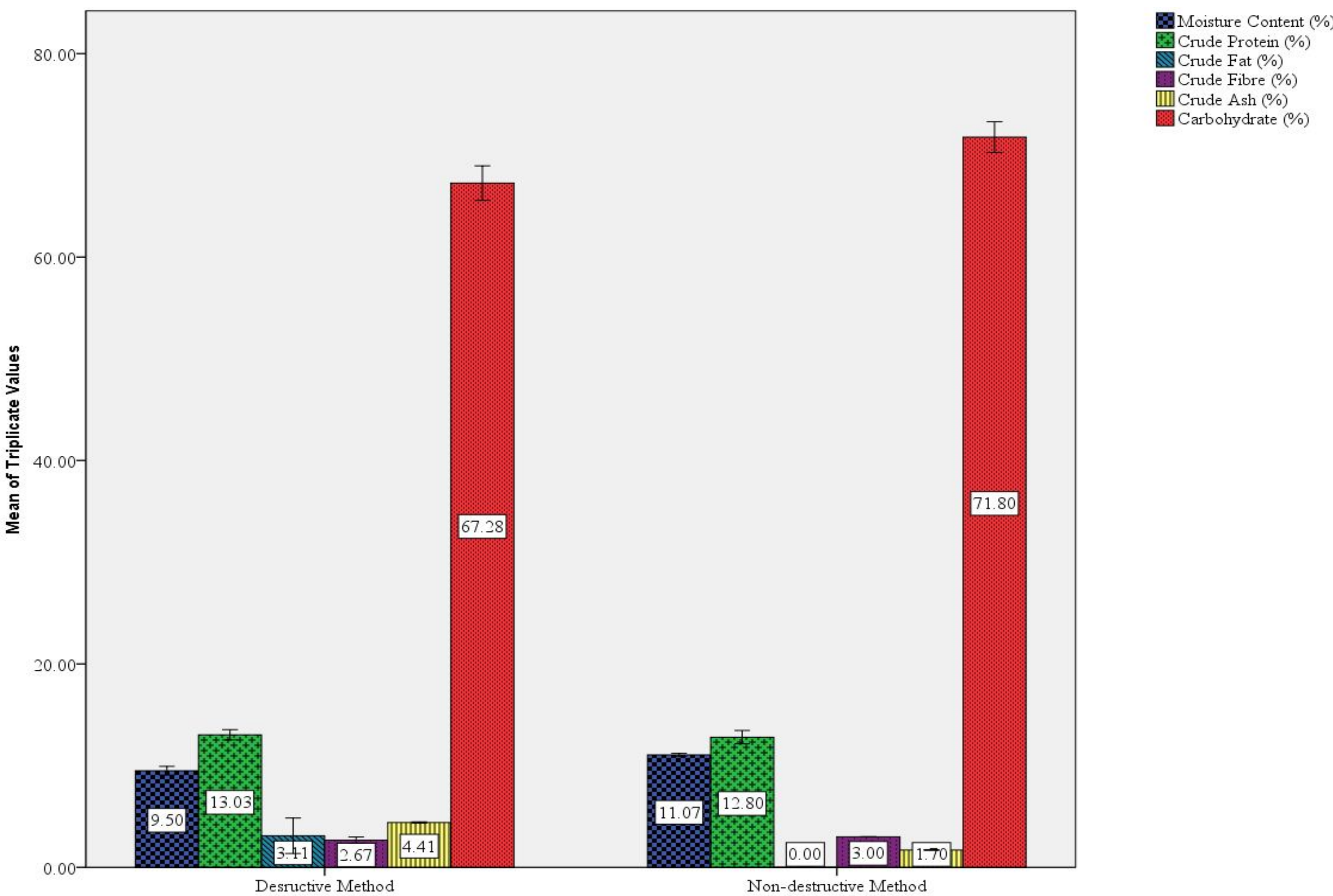

Figure 1. Error Bars: 95% CI for the sample parameters.

desired as aqueous and gel food preparations due to the ever promising constituents of the grain.

The crude fat content obtained for wheat in this study was observed to be $3.11 \pm 0.41\%$ when destructive technique was used (Table 1) which indicate similar trend as observed with the findings by Adams et al. (2002) where the value for wheat obtained was $3.15 \pm 0.40\%$ for the production of noodles. This is also an indication that the essential fatty acid (oleic, linoleic, and linolelic) constituents and proportions of fat content of the wheat grain will be sufficient enough to aid the body's absorption of vital nutrients which are required for human health.

Crude fibre content of wheat also indicates that there were significant differences between the values obtained for wheat grain when both methods were compared with each other ($P < 0.05$). Wheat 3.00 ± 0.00% had significantly higher fibre content in non-destructive approach over the destructive value of wheat 2.67 ± 0.07% when the destructive measurement technique was used. The trend of the obtained results are low when compared with previous research for wheat 12.26 ± 0.00% as reported by Atwell (2001) and Alan et al. (2000). This could be as a result of varietal differences in the cultivar and environmental conditions which give wide variation in chemical characteristics observed within and among the grains. However, the results obtained in this work were observed to be higher than the reported values for wheat 1.28 ± 0.6%, necessary for the production of noodles (Akanbi et al., 2011). The implication of higher fibre content for the grains is to help the consumer to be healthier by keeping the bowels working and moving other foods quickly through the body for metabolic purposes.

Ash content of wheat was significantly different ($P < 0.05$) for both the destructive and non- destructive measurements. For the destructive method, the ash content of wheat 4.41 ± 0.01% was significantly higher than the recorded value of wheat 1.71 ± 0.01% when non-destructive approach was applied. However, in the destructive measurement, the value was observed to be higher than the findings for wheat 2.25 ± 0.00% (Akanbi et al., 2011; Subramanium and Metta, 2000). But the ash content obtained from the non-destructive measurement was observed to be lower when compared with the reported value 2.25 ± 0.00% for wheat by the same researcher. This could be an indication that the pericarp, locular tissues and seeds vary substantially with respect to cereal grain constituent depending on the cultivar and environmental condition which could be the possible reason for the observed differences. Differences in bulk density and texture of the grains could be other possible reasons for the two significant sources of errors in NIR reflectance measurement.

The carbohydrate content obtained in this work as shown in Table 1 for wheat also indicates significant differences in the grain sample used for the analysis for both the destructive and non-destructive measurements when compared with each other. The non-destructive measurement quantified higher significant carbohydrate content for wheat 71.80 ± 0.35% over the recorded value of wheat 67.27 ± 0.39% when the destructive method was applied. However, this trend is in agreement with the reported range 65 to 75% necessary for the production of pastry products (Belderok et al., 2000).

CONCLUSIONS

Proximate compositions deserve to be adequately and economically determined. In view of this, technological advancement and utilization of new developed equipment need to be put in place for many research institutes and food processing industries in Nigeria and elsewhere to ensure quick method of determining nutritional constituents in agricultural products non-destructively.

The results of this study support the research and industrial application of utilizing the non-destructive method to determine proximate compositions of cereal grains (wheat) over the destruction (conventional) method. This suggests that non-destructive method of proximate compositions determination can economically replace the conventional destructive (chemistry based) method effectively without destroying the proximate compositions of the food products.

However, the utilization of the non-destructive equipment for the determination of proximate compositions lies primarily on ease applications. Cereal grain industries, food processing industries and research institutes now have a tool for faster, economical and non-destructive means of proximate composition determination for their grains.

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