Giant Rat Tail Grass (Sporobolus pyramidalis) grain as a novel food for human consumption: an infrared study

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Research Article

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Abstract

Giant Rat Tail Grass (GRT) is an introduced pasture plant species to Australia. The low palatability of GRT to livestock and its high seed count and drought tolerance are contributing factors to define this species as invasive pest. An alternative use for the plant would potentially alleviate the requirement of landholders to engage methods of eradication. The aim of this study was to collect and analyse the infrared fingerprint of GRT grain to assess its nutritional suitability for human consumption. Whole grain samples of GRT (n = 10) and teff (n = 3), a staple African grain, were analysed using attenuated total reflectance mid infrared spectroscopy (ATR-MIR spectroscopy). The MIR absorbance values of protein, lipids, and starch of each GRT and teff samples were calculated and compared. The MIR results indicated that GRT seeds have comparable levels of protein, lipids, and starch comparable to other commercially available seeds such as teff. The MIR spectra of GRT seeds showed that they have potential nutritional value for human consumption; however, the concentration of protein, starch and lipids was not determined. Further research is required to quantify the levels of these nutrients and suitability of GRT seeds for human consumption.

Introduction

Giant Rat Tail Grass (GRT) *Sporobolus pyramidalis* is a robust tufted grass introduced to Australia via contaminated pasture seed. GRT is distributed from north of Cape York in Queensland to the New South Wales Central Coast [1]. This native African grass has adapted to the climatic conditions to such a degree that it now constrains pasture production [2] especially in areas of overgrazing and soil disturbance [1]. The plant can grow up to 2 m in height and the seed head can produce up to 85,000 seeds which are easily spread via livestock (native, domesticated, and feral animals), as well as by farm machinery. Although GRT has characteristics of high seed production, drought tolerance, and vigorous seedling growth, the low palatability to livestock renders it considered weedy in the agricultural/grazing industry. GRT is a declared invasive plant under the Queensland Biosecurity Act 2014 requiring landholders to adopt management and eradication practices at great financial burden [1]. These practices are often unsuccessful, resulting in increased viable conditions for the plants to thrive.

Sporobolus species are noted to be wild food, harvested, and consumed during periods of food shortages in Africa when staple foods are unavailable [3]. It has been documented that *Sporobolus* species were consumed in Ethiopia 1999 when food shortages occurred due to a prolonged dry season, including *Sporobolus indicus* which is described as a ‘weed grass with tiny seeds like teff grains’ [3]. Similarly, Native Americans ground the seeds of *Sporobolus* species to make a tasty flour [4]. However, no information in relation to human consumption of the *Sporobolus* species nor information of the nutritional properties of the plant or seeds is evident in the literature. As *Sporobolus* species are considered wild foods, no information on the yield (predicted or actual) is available.

Teff (*Eragrostis teff*) is also an African native grass and has become a major food crop due the nutritional value of the grain as well as the resilience of the plant to harsh environmental conditions [5].

Teff production has become the single most important crop in Ethiopia [6] with predicted yields between 1.37 t. Ha^{-1} and 1.99 t. Ha^{-1} in 2015 and 2022, respectively [7]. Teff is consumed by more than 70% of the Ethiopian population [8] and constitutes two-thirds of the daily protein intake [9]. Teff is mostly used to make a spongy fermented flat bread called Injera [10]. In addition to the seeds, the straw is highly valued as a source of animal feed (particularly during drought), as well as being used in conjunction with mud and plaster in the construction of the walls of grain stores and traditional huts [11]. GRT and teff are both members of the *Poaceae* family [12]. Although these plants display similar observable characteristics and properties, a literature search does not reveal any prior research into the nutritional value or functional properties of GRT for human consumption.

Vibrational spectroscopy techniques (mid and near infrared) are well-established for the determination and evaluation of the chemical composition of food ingredients and foods due to their rapidity, simplicity, safety, and ability to measure multiple attributes simultaneously without significant sample preparation [13]. Mid-infrared (MIR) spectroscopy has been used to determine the chemical composition and nutritive value of cereal grains and other agricultural products [14]. MIR spectroscopy collects the fundamental vibrational and rotational stretching vibrations of molecules, which gives the sample's unique chemical profile [15]. The 400 to 4000 cm^{-1} of MIR is a robust and reproducible segment of the electromagnetic spectrum that can reliably identify differences in sample composition [16]. The fingerprint region has been also reported by different authors as proxy to characterise the composition and nutritive value of seeds, cereals, and legumes [17].

The aim of this study was to collect and interpret the infrared fingerprint of GRT grains to determine their potential nutritional suitability for human consumption. This study will add information to support the research question whether the chemical composition of GRT is comparable to other starchy grains to deem it suitable for human consumption.

Materials and Methods

Samples

Samples of mature GRT grain heads were visually identified and manually collected from pastures on Kandanga Farm, an organic beef producing farm located in Kandanga, Queensland, Australia. The samples were dried in a domestic dehydrator (AMBIANO Food dehydrator, Model KYS-336D) at 60°C for 36 h as described by Han et al [18]. Due to the lack of availability of fresh grains, 'Teff Tribe' teff whole grain samples were purchased from a local food retail outlet. The origin of the teff grain samples was unknown.

Attenuated total reflectance mid infrared spectroscopy.

The collection of the infrared fingerprint of the GRT (n = 10) and teff (n = 3) was achieved using an attenuated total reflectance mid infrared spectroscopy (ATR-MIR). Randomly selected single seeds were scanned by placing each sample on top of the ATR diamond cell and held in place using the pressure applicator, as previously described by Cozzolino, Roumeliotis & Eglinton [19]. The platinum diamond ATR single reflection sampling module cell mounted in a Bruker Alpha instrument (Bruker Optics GmbH, Ettlingen, Germany) was used to scan each sample. Each sample of GRT and teff was tested once where the ATR -MIR spectrum was recorded for further analysis. Bruker Optics provided the OPUS software version 7.0 on which the spectra were recorded. The final spectrum is the average of 24 scans taken in the mid infrared range between 4,000 and 400 cm^{-1} [20]. The region between 2,400 and 1,900 cm^{-1} was removed from the analysis due to the interferences of water vapour and CO_2. Air was used as the reference background spectra and collected every two samples [20]. The ATR cell was cleaned with a mixture of 70% ethanol in water (v/v) and dried with laboratory Kimwipes® between samples.

Data Analysis

The ATR-MIR spectrum was exported from the OPUS software to the Excell (Microsoft, USA) for analysis. The absorbances from the relevant frequencies were averaged and standard deviation were calculated. Protein amide I and II (between 1,700 and 1,600 cm^{-1} and 1,580 and 1,484 cm^{-1}), non-structural (*e.g.*, starch, amylose, and amylopectin) and structural carbohydrates (*e.g.*, cellulose, hemicellulose) between 1,250 and 990 cm^{-1}, and lipid peak height intensities and their ratios were determined. These chemical function groups were identified according to published reports [21, 22].

Results

Figure 1 presents the ATR-MIR spectra of the individual and whole GRT seed samples. We observed two distinctive groups of samples in Fig. 1. These differences can be attributed to either the size of the seeds or maturity. Some of the seed analysed were too small and were difficult to clamp into the ATR cell without damage. In addition, it was difficult to know the maturity stages of the seeds as they were collected from the wild. The ATR-MIR spectra of the GRT seed samples analysed showed three distinctive regions around 3,300–2,800 cm^{-1}, in the fingerprint region around 1,600 cm^{-1}, and around 1,000 cm^{-1}. Frequencies at 3,000–2,800 cm^{-1} are associated with the presence of lipids and fatty acids [23]. In the fingerprint region, from 1,700–1,600 cm^{-1}, these frequencies are associated with the amide I from the proteins and other compounds having nitrogen in their molecule [24]. The frequencies in the range between 1,200 and 1000 cm^{-1} are related with carbohydrates and polysaccharides (*e.g.*, starch); amylose and amylopectin have been also reported to absorb in the range between 1,100 and 900 cm^{-1}. Frequencies between 1,400 and 1,300 cm^{-1} might be associated with the presence of phenolic compounds (C-C-C aromatic ring stretch) that constitute the seed coat [25]. These results were consistent with those reported by authors testing seeds from cereals such as wheat and barley [26, 20]. Figure 2 shows the MIR spectra of the teff samples analysed. The same trends in the MIR spectra as those described for GRT were observed.

Figure 3 shows the absorbance values corresponding with proteins (around 1,641 cm^{-1} associated with amide I of N-H bend, C-N stretch, and C-C stretch), starch and polysaccharides in the 1,150–1,024 cm^{-1}

region and with lipids (between 2,900 and 3,300 cm^{-1}). Similar results were reported by other authors analysing Acacia seeds [27] or the identification of mutants in Plantago seeds [28]). We observed a large variability between the samples. This variability is expected as GRT is a wild plant species. The data indicated this variability was larger in the absorbances associated with either protein or starch. The comparison between the average MIR spectra of the GRT and teff seed samples is presented in Fig. 4. We observed that the absorbance values from the teff seed samples were higher than those observed for GRT. This might indicate that the concentration of lipids, protein and starch is higher in Tef seeds compared with GRT.

Discussion

The analysis of the infrared fingerprint of GRT collected using ATR-MIR spectroscopy was undertaken to address the hypothesis that this invasive plant could be a novel food for human consumption. Current guidelines and efforts to eradicate GRT [1] have not been successful, resulting in rapid spread and constrains on productive pastures. An alternative use for the plant and grains could potentially reduce the social and economic impacts of GRT. In this study, harvest of the GRT grain was achieved by visual identification and random selection of plants which was mirrored by the variability observed in the MIR results. Consequently, the grain samples were not of equal maturity, which influenced the variability in the infrared fingerprint of the seeds. However, the peaks in the MIR spectra allowed for the identification and interpretation of absorbances associated with lipids, proteins, and starch in the GRT samples analysed.

Figure 2 illustrated the prediction of the functional groups of teff with samples 2 (S2) and 3 (S3) having very similar results. Differences in the MIR spectra of the samples could be attributed to either the small size of the grain (spectra collection) or by the sample may not have been at a similar stage of development or maturity as that of S2 and S3. Interestingly, the lipid value is within a similar absorbance range as S2 and S3, which suggests that sample 1 (S1) had some issues during the spectra collection. Furthermore, this sample was not included in the analysis as these differences are strictly associated with differences in chemical composition. It is also important to note that the teff samples were purchased from a retail outlet where the origin, processing and maturity of the grain was unknown.

Figure 4 showed the average of the absorbance values for both species of seed grain analysed. Accordingly, the seed samples of GRT did not contain as high levels of the functional groups as were observed in teff. The most evident differences between the two species analysed was that of the protein content. Individual GRT lipid absorbance values (see Fig. 3) indicated that 2 of the GRT samples contained higher levels than that of teff.

Overall, the comparison between the MIR spectra of GRT and teff seed samples (Figs. 1 and 2) indicated that teff tends to have higher level of protein, similar levels of starch, and lower levels of lipids in comparison to some seed samples of GRT. Most importantly, the MIR fingerprint of the seed samples indicated that GRT has the potential nutritive composition that may be suitable for human consumption but not at the same nutritional quality as teff in terms of protein content. However, further analysis should be conducted to exactly quantify the levels of lipids, proteins, starch, and other nutrients of importance in the GRT seeds.

To the best of our knowledge this is the first report of nutrient composition analysis of GRT. Some limitations of this study include the fact that the collection of the GRT samples was not systematic, consequently samples could have been of varying physiological stages (*e.g.*, maturity). In addition, as the samples were collected by the author from various pastures on Kandanga Farm QLD, the nutrient content could have varied due to the possible environmental factors (*e.g.*, variation in soil composition). The drying equipment was of domestic quality and had not been assessed to be operating at the exact temperature of 60°C.

The observed variation between the samples of GRT indicated that ongoing research at varying stages of development is required to pinpoint the stage at which the nutritional value of the grain is at the optimum. For example, GRT sample 8 had a more favourable nutritional profile than other samples. In addition, the identification of the micronutrient values, lipid profile, resistant starch, and water content of GRT will be required to establish whether GRT grain may be suitable for human consumption.

Conclusions

In conclusion, this study showed that the infrared fingerprint of GRT can be used as proxy to evaluate the nutritive value of this seed (lipids, proteins, and starch), thus adding to the information about the suitability of GRT for human consumption. Previously, research has not been conducted on this topic and as such this study opens the pathway for further research such as the determination of the optimal harvesting time, maturity, or processing (*e.g.*, drying) of the GRT seeds to use as food ingredient. In addition, further analysis focus in the determination of micronutrients, lipid and fatty acid profile, resistant starch, and water activity, among others will be also required to determine if GRT grain is suitable for human consumption.

Abbreviations

GRT Giant Rat Tail grass

ATR-MIR Attenuated total reflectance – mid infra-red

QLD Queensland

IR infra-red

Declarations

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Author Contribution

V.K. wrote the main manuscript text and prepared all figuresD.C. contributed and reviewed and edited the main manuscript text and all figuresM.H. and J.VDP contributed, reviewed and edited the main manuscript text and figuresall authors reviewed the final manuscript

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Figures

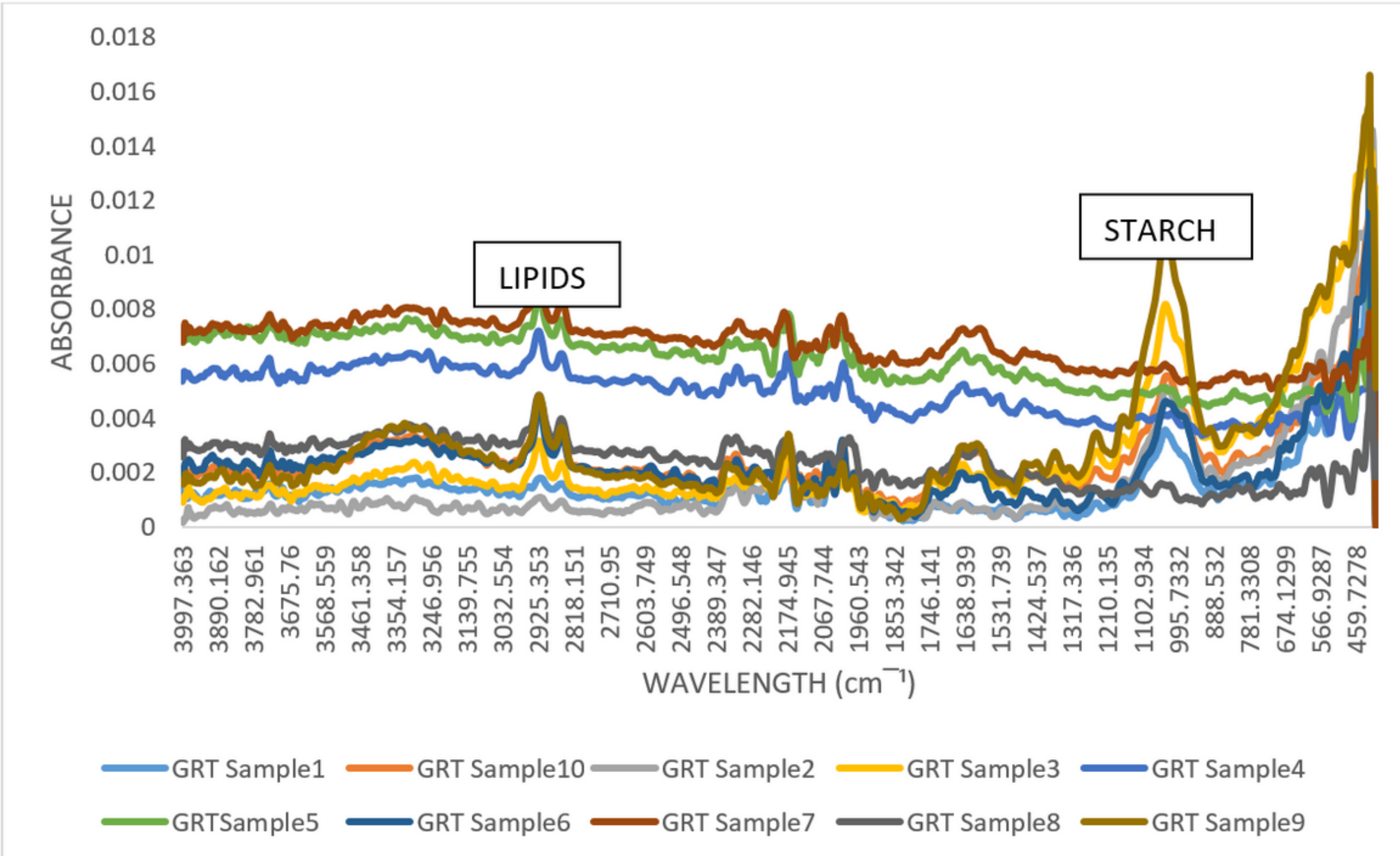

Figure 1

Mid infrared spectra of Giant Rat Tail Grass grain samples analysed using attenuated total reflectance mid infra-red spectroscopy.

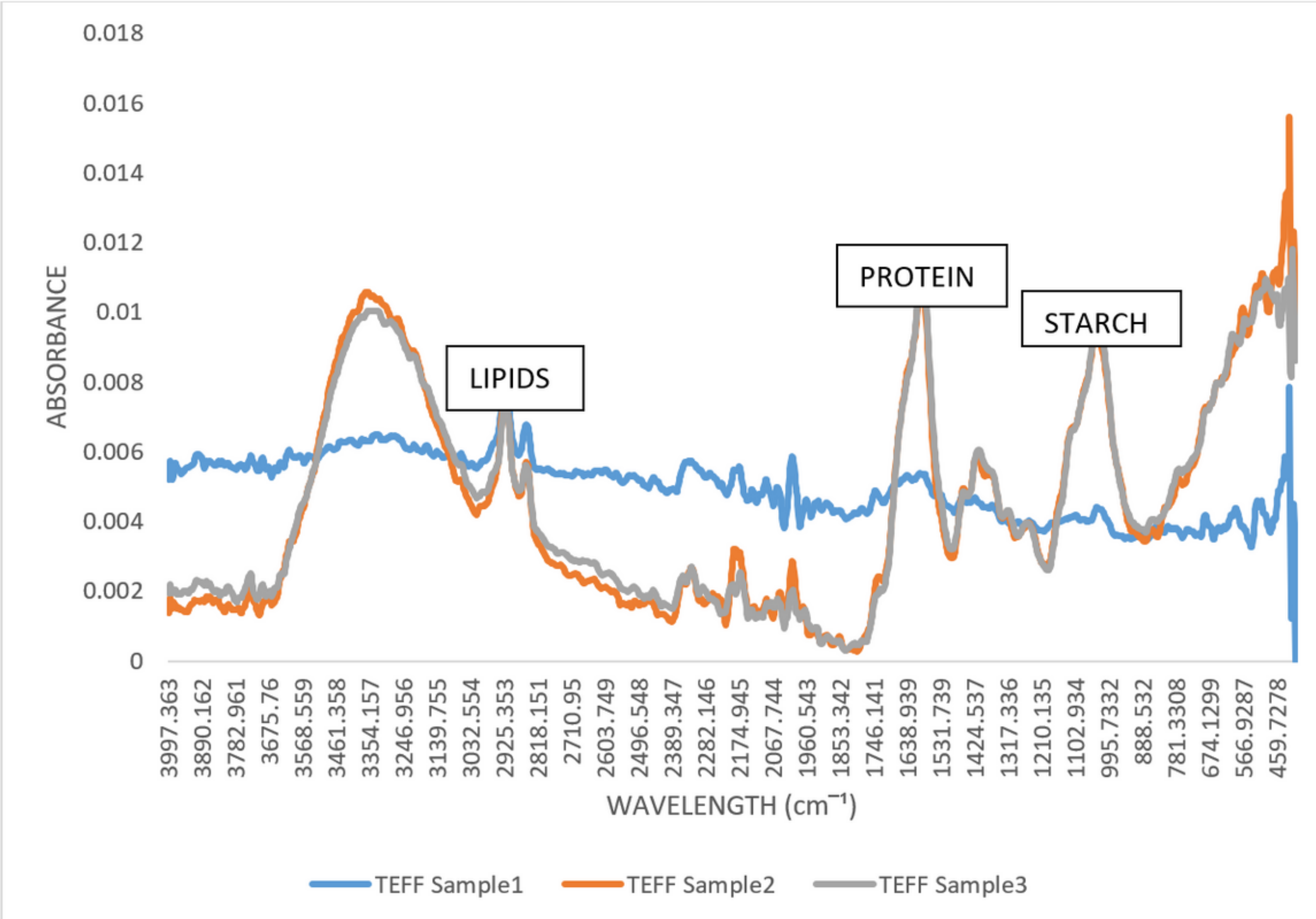

Figure 2

Mid infrared spectra of Teff grain samples analysed using attenuated total reflectance mid infra-red spectroscopy.

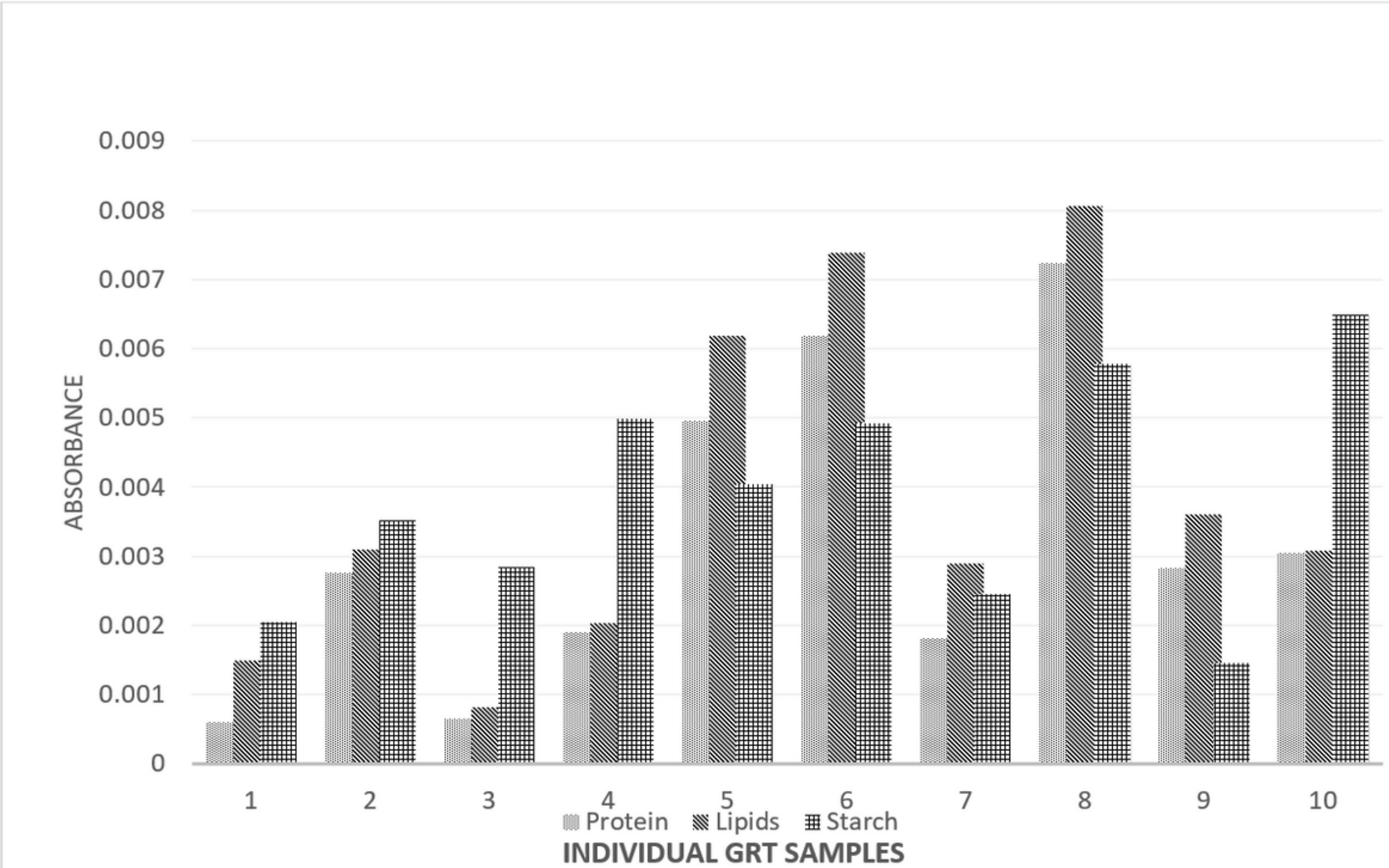

Figure 3

Absorbance values at specific frequencies in the MIR regions for starch, protein and lipids of individual GRT grain samples as identified using total attenuated mid infra-red spectroscopy.

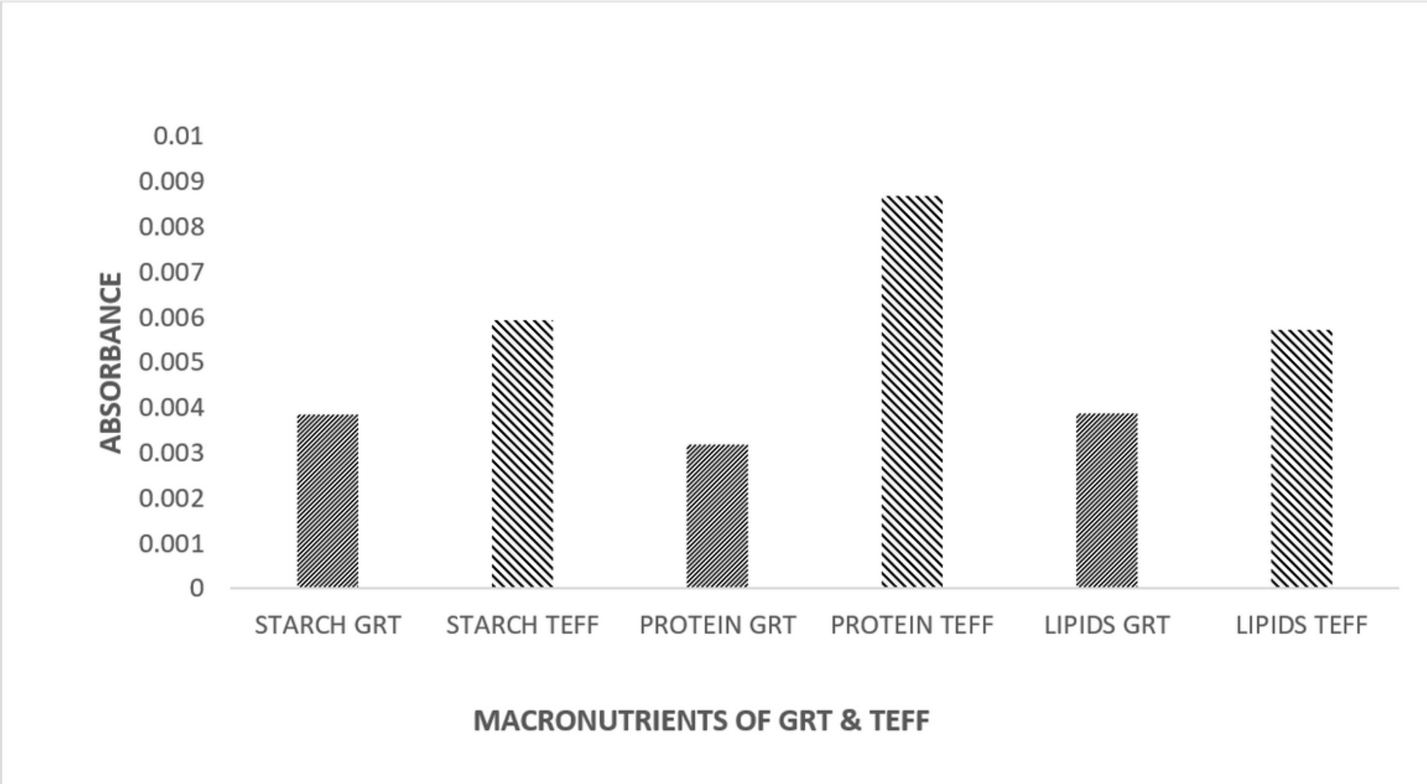

Figure 4

Comparison of the average absorbance values at specific frequencies in the MIR regions for starch, protein and lipids as analysed in GRT and Teff.