Application of a "Glucose Release Index" to assess physical and chemical characteristics of cereal grains that may influence starch digestion and subsequent energy supply to monogastrics

Submitted by

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Summary

In the pig and poultry production industries, energy forms the largest and the greatest cost pressure when a diet is formulated. In Australia, cereal grains such as barley, sorghum, and wheat are the main dietary energy sources, comprising more than 60% of the diet in many cases. Traditionally, during diet formulation, the energy value of a grain has been represented by a single figure for that particular grain type. However, several studies have indicated that the energy availability from different grains fed to pigs and poultry varies significantly even within one grain cultivar. Given these findings, the use of a single value to represent the energy of each grain type during diet formulation, can lead to inefficient utilisation of dietary resources by animals, and thus decreased animal performance and consequently, a decrease in profit for the pig and poultry production industries.

Thus, there is an opportunity to develop a rapid and reproducible *in vitro* assay to accurately assess the available energy values and nutritional quality of each grain type. In order to develop such an assay, further understanding of factors that affect the available energy values of grains need to be explored.

Starch, which is hydrolysed into glucose by animals, is the most abundant energy component in cereal grains, and there is evidence suggesting that variations in digestible or metabolisable energy values may be related to the extent of starch digestibility. For example in poultry, variations in the *in vitro* digestibility of starch between several wheat cultivars have been shown to correlate with their *in vivo* available metabolisable energy values. However, it is not known to what extent starch digestibility varies between cultivars of other grain types such as barley and sorghum.

There is an increasing body of evidence suggesting that differences in the physical and chemical properties of cereal grains may play an important role in influencing starch digestibility and, consequently, animal performance. Thus, the general hypothesis of this study was that starch digestibility varies between barley, sorghum and wheat, and between cultivars within grain types and this is related to specific chemical and physical characteristics of the grains. To examine this, the following issues were investigated using 18 barley, 15 sorghum and 10 wheat cultivars: 1) an *in vitro* glucose release index (GRI) assay was developed to assess starch digestibility within and between the cereal grain types and, 2) the GRI was correlated to both starch-related (e.g., starch content, starch granule size, the amylose to amylopectin ratio, starch gelatinisation properties) and non-starch-related (e.g., non-starch polysaccharide composition, kernel hardness, the presence of

protein matrix and milling quality) physical/chemical characteristics within and between the cereal grains.

Results revealed significant variations in the GRI both between grains and within a given grain type. The GRI values ranged between 27 - 45%, 25 – 54% and 32 – 53% in barley, sorghum and wheat respectively. Correlation analysis revealed that the GRI in barley, sorghum and wheat was influenced by the physical and chemical characteristics of starch- and non-starch-related grain properties, although the type of characteristic influencing GRI was specific to the grain type. In barley, the ratio of amylose to amylopectin, starch gelatinisation and kernel hardness influenced the GRI. In sorghum, the GRI was influenced by the ratio of amylose to amylopectin, the presence of a protein matrix surrounding starch granules and kernel hardness. Finally in wheat, the presence of protein matrix and milling quality influenced the GRI. It was also shown that the extract viscosity of grains within barley and wheat, but not sorghum, varied significantly.

In conclusion, this study 1) indicated that the GRI may be influenced by some physical and chemical characteristics of cereal grains, and that these characteristics are specific to the type of grain, and 2) identified that future work should establish the relationship between GRI *in vivo* starch digestion and absorption of cereal grains.

The physical and chemical characteristics that may influence starch digestion are discussed in relation to their potential physiological effects on energy digestion, and utilisation in animals. The information generated will provide a basis for future studies that will ultimately assist in the design of *in vitro* assays to predict energy availability from barley, sorghum and wheat grains fed to pigs and poultry, and contribute to the more efficient use of grains in monogastric production systems.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any University or other Tertiary Institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent for this copy of my thesis, when deposited in the University Library, to being available for loan and photocopying.

Mohammad-Reza ZARRINKALAM

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Dedication

This thesis is dedicated to my parents, Mr Hossien Zarrinkalam and Mrs Zahra Zarrindokht Pourjalali for believing in my dreams and giving me encouragement to pursue them.

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Abbreviations

AME	apparent metabolisable energy
DE	digestible energy
GRI	glucose release index
LSD	least significant differences
ME	metabolisable energy
MJ	megajoule
MPa.s	millipascal seconds
NSP	non-starch polysaccharides
RVA	rapid visco analyser
RVU	rapid visco analyser units
SGs	Starch granules