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# THE RELIABILITY OF DRY MATTER, SPECIFIC GRAVITY, STARCH AND GLYCAEMIC INDEX TO CLASSIFY POTATOES

Van Niekerk, C.; Schönfeldt, H.C.; Hall, N., & Pretorius, B.

Institute of Food Nutrition and Well-Being, University of Pretoria, Pretoria, South Africa

## ABSTRAT

There is a global increase in the production, processing and consumption of potatoes, especially in developing countries. The scale of the different varieties available today has led to a demand by end users to have some indication of fit for purpose. Reliable, scientifically validated objective methods are needed to group potatoes in order to develop such a system. The reliability of specific gravity, dry matter and starch content and glycaemic index were determined as these measurements are often used to describe tuber characteristics. However, the reliability of these methods differed within and between studies. Dry matter content was found to be the most robust analytical method to group potatoes together. Specific gravity proved to be an unreliable method due to the lack of standardisation of the method. Glycaemic index delivered different results using a single cultivar in an inter laboratory study.

**Keywords:** Dry Matter, Specific Gravity, Glycaemic Index, Potatoes

## 1 INTRODUCTION

Potatoes have been a staple crop in the diets of many cultures, ranging from the original boiled spud to ready to eat processed products such as potato chips. This increase in consumption has made the potato industry a rapid growing part of the agricultural sector. Globally there are more than 4 000 *Solanum tuberosum L.* species grown commercially as well as in the wild (International Potato Center, 2014). New potato cultivars are constantly being developed and these new cultivars might be more resistant to diseases, grow better in certain agronomical conditions or are developed to fill a need in the consumer market. Different cultivars have varying shapes, colours, chemical compositions and textural qualities (Potatoes South Africa, 2011). Agronomical conditions i.e. growth, location, watering and temperature may further differentiate one batch of potatoes from another (Booysen, et al., 2013).

  

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Due to the magnitude and diversification of the crop and its multifaceted role in human diets, systems or groupings are required to make is easier for the end user to identify which cultivar or batch would be best for their purpose. Such batch or cultivar specific classification systems are used globally to classify potatoes into textural, processing or health related classes (Pinhero, et al., 2016). Potato classification systems are unique to each country as varieties are dictated by agronomical conditions. In the United Kingdom a revised potato classification system was implemented in 2012. This system classified potatoes for culinary application; fluffy potatoes are ideal for baking, salad potatoes are best when boiled and smooth potatoes are best when preparing mash (National Potato Council, 2014). In contrast to the cooking method classification of the UK, potatoes in America are classified according to colour and shape i.e. round white, long white, red, yellow, blue, purple and Russet Burbank with little attention given to their specific culinary applications (United States Potato Board, 2014). The revised South African potato classification system as of 2012 groups potatoes into three textural groups. Waxy potatoes are ideal for boiling as they keep their shape, floury potatoes should be used to prepare mash as they deliver a smooth end product and waxy/floury potatoes can be used for all applications (Potatoes South Africa, 2011).

Sensory panel analysis are a preferred measurement for textural classification and eating quality. However, this is an expensive and time consuming method (Chen & Opara, 2013). Therefore, objective measures such as specific gravity (which was used to develop the South African potato classification system), dry matter and starch analysis are frequently used to develop and categorise batches of potatoes accordingly (Potatoes South Africa, 2011). These objective measures are focused on determining the internal textural properties of tubers by means of the ration of dry matter to moisture in the tuber (Thybo, et al., 2000). However, contradicting results for studies using these methods have been reported (Fernando & Slater, 2010).

From a nutritional point of view potatoes comprise mostly of carbohydrates that can have an effect on glucose levels in the human body. However, it has been reported that different cultivars have different glycaemic loads. Glycaemic index and glycaemic load measures are thus also considered methods which could classify potatoes from different cultivars into different categories based on their ability to raise blood glucose (Lovat, et al., 2015). However, the analytical method used for *in vivo* glycaemic index analysis comprises of a variety of intricate steps as well as external influences which can have an effect on the reliability of the end results (Venn & Green, 2007).

The South African potato crop is made up of a variety (more than 80) cultivars grown in over 16 different production regions under suitable agronomical practices (Potatoes South Africa, 2011).

  

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Although technically a vegetable, this tuber is seen as one of the starchy staple foods of the South African population, other staple foods include maize meal porridge, bread and rice (Bureau for Food and Agricultural Policy, 2015). The paper thus aimed to determine whether specific gravity, dry matter and starch are reliable predictors of potato texture, and if glycaemic index and glycaemic load are reliable methods to class potatoes based on their ability to raise blood glucose in humans.

## 2 METHODOLOGY

The scope and variety of potatoes planted in South Africa over the different climatic regions has necessitated broad data gathering over an extensive period of time to ensure a representative sample is obtained. For this paper data from four different studies on specific gravity, dry matter, starch and glycaemic index were gathered and evaluated. The original data from all four studies were collated into excel spreadsheets and evaluated using statistical analyses. Due to the individual nature of the different datasets, the methodology used for each dataset was unique and will be discussed in detail in the appropriate section.

## 3 DRY MATER, SPECIFIC GRAVITY AND STARCH

### 3.1 Methodology

To test if dry matter, specific gravity and starch are reliable methods to categorise potatoes data from three separate studies were used. Objective data on specific gravity, dry matter and starch (Table 1) was compared to sensory profiles in order to evaluate reliability of these measures to categorise potatoes according to their sensory cooking qualities.

For the first study data from six production regions for ten potato cultivars was used (Van Niekerk, et al., 2016). The tubers from these trials underwent a variety of objective analysis over a three year period. Tubers and regions with the most repeats were selected to enable statistical evaluation.

Secondly, data from eleven different cultivars planted in one production region was analysed (Unpublished report for Potatoes South Africa, 2015). For this study the specific gravity and dry matter values for eleven different cultivars was determined. These tubers underwent objective analysis at the University of Pretoria's NutriLab including dry matter, starch and specific gravity.

  

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For the third study data from five different trials conducted over five regions on eleven different cultivars was compared (Leighton, et al., 2010). Data was statistically analysed to determine which attributes best declared variance in the data for specific gravity, starch and dry matter.

**Table 1: Analytical methods used for relevant objective analysis**

| Analysis | Method |
|---|---|
| Starch | Enzymatic spectrophotometer (In-house method) |
| Dry matter | AOAC, 2000. Official method of analysis 934.01 (Giron, 1973) |
| Specific gravity | $Specific\ gravity = \frac{Weight\ in\ air}{(Weight\ in\ air - Weight\ under\ water)}$ (South African Department of Environment and Primary Industries, 2000) |

### 3.2 Statistical analysis

The data gathered in MS Excel spreadsheets was inspected for outliers using a residual test. It was subsequently analysed using GenStat for Windows (2008) statistical computer programme (Payne, et al., 2012). For the first study a Restricted Maximum Likelihood (REML) analysis was performed over cultivars between regions and over regions between cultivars to determine whether certain objective tests can indicate textural differences in different cultivars over the different regions at a 5% level of significance. For the second and third study a Partial Least Squares regression procedure (PLS) of GenStat was used. In study two a PLS was to establish the correlation between the set of objective measures (Payne, et al., 2012). A correlation of 0.8 and higher indicates a significant correlation and a correlation of 0.6 and higher indicates a fair correlation (Schippers, 1976). For the third study PLS was applied to analyse the relationship between objective test measurements and sensory evaluations, with the objective of determining which attributes best describe variance in the data.

### 3.3 Results

Study one showed significant differences in specific gravity between all cultivars over regions except in a single region, namely Loskop Valley (Limpopo province). Significant difference in specific gravity values was seen in the Almera cultivar over the different regions (Table 2). It was concluded form this study that specific gravity was the only consistent indicator of differences between cultivars over regions and was the only objective measure included to evaluate the intrinsic textural properties of the tubers.

  

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**Table 2: Specific gravity of ten potato cultivars over six regions**

| Specific gravity | | | | | | | |
|---|---|---|---|---|---|---|---|
| Region | | Limpopo | Mpumalanga | Eastern Free State | Western Free State | South-West Free State | Loskop Valley |
| Median | n-value | n=7 | n=4 | n=6 | n=7 | n=3 | n=4 |
| Cultivar | p-value | p<0.001 | p<0.001 | p<0.001 | p<0.001 | p=0.039 | p=0.831 |
| Almera | p=0.046 | $1.060^{a,i,ii}$ | $1.058^{a,i}$ | $1.06^{a,i}$ | $1.058^{a,i}$ | $1.069^{b,i}$ | - |
| Avalanche | p=0.751 | $1.069^{i,ii,iii}$ | - | $1.067^{i,ii}$ | $1.065^{i,ii}$ | - | - |
| BP1 | p=0.433 | $1.071^{i, ii,iii, iv}$ | 1.077 | - | $1.071^{ii,iii}$ | - | - |
| Darius | p=0.519 | - | - | $1.085^{v}$ | $1.082^{iv}$ | - | - |
| Fabula | p=0.915 | $1.59^{i}$ | - | $1.058^{i}$ | $1.058^{i}$ | - | - |
| Fianna | p=0.295 | $1.082^{iv}$ | $1.09^{iii}$ | $1.081^{iv,v}$ | - | - | 1.073 |
| Mondial | p=0.591 | $1.066^{i,ii,iii}$ | $1.062^{i}$ | $1.065^{i}$ | $1.063^{i,ii}$ | $1.069^{i}$ | 1.072 |
| Sifra | p=0.654 | $1.068^{i,iv}$ | $1.065^{i}$ | $1.067^{i,ii,iii}$ | $1.071^{ii,iii}$ | - | - |
| UTD | p=0.161 | $1.07^{i,ii,ii,iv}$ | - | $1.076^{ii,iv,v}$ | $1.079^{iii,iv}$ | - | 1.069 |
| Valor | p=0.269 | $1.069^{i,iii}$ | $1.071^{ii}$ | $1.073^{ii,iii,iv}$ | $1.07^{ii,iii}$ | $1.081^{ii}$ | - |

Super script letters indicate significant differences over regions
Roman numerals indicate significant differences over cultivars

For study two a correlation matrix was analysed to determine correlations between dry mater and specific gravity. Dry matter and specific gravity correlated less with each other than expected at r=0.6831.

The third study was completed over two years and consisted of four trials. Sensory and objective tests were conducted in all four the trials to determine which measures best declared variance in the data. The first dimension declared variance in the sensory data while the second dimension declared variance in the objective analysis. Only the objective analysis will be discussed for the purpose of this paper.

Dry matter declared variance in all four the trials; r=76.1, r=78.3, r=86.0 and r=72.3 respectively. Starch declared variance in the second dimension in three (Trial 1, 2 and 3) of the four trials; r=58.1, r=67.8 and r=66.5 respectively. Specific gravity declared variance in two of the four studies; r=58.2 (Trial 2) and r=81.0 (Trial 4).

  

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From these four trials it was seen that dry matter and starch were the best predictors of variance in data between the different regions over cultivars. Dry matter and starch delivered more consistent results than specific gravity analysis.

Significant differences were seen in the specific gravity between cultivars over all the regions in all four the trials. Dry matter between cultivars differed significantly over the different cultivars in Trials 2, 3, and 4. Starch values between cultivars showed differences in three of the trials; 1, 2, and 4. Climatic and agronomical differences in the different regions may be the main influencers of difference seen in the objective values of the different cultivars (Booysen, et al., 2013).

**Table 3: Least square mean values of the objective tests**

| **Least square mean values of objective tests (n=5)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivars** | **p-value** | **Mondial** | **BP1** | **UTD** | **VDP** | **Caren** | **Fabula** | **Valor** | **Buffelspoort** | **Fianna** | **Darius** |
| **Trial 1** | | | | | | | | | | | |
| Specific gravity | <0.001 | $1.05^{d}$ | $1.07^{bc}$ | $1.08^{ab}$ | $1.07^{bc}$ | $1.08^{a}$ | $1.06^{c}$ | - | - | - | - |
| Dry matter | <0.001 | 17.54 | 22.04 | 23.44 | 19.48 | 16.27 | 16.72 | - | - | - | - |
| Starch | <0.001 | $12.02^{bc}$ | $15.28^{a}$ | $15.70^{a}$ | $12.60^{b}$ | $9.45^{d}$ | $11.45^{c}$ | - | - | - | - |
| **Trial 2** | | | | | | | | | | | |
| Specific gravity | <0.001 | $1.051^{b}$ | $1.079^{a}$ | - | - | $1.074^{a}$ | - | - | $1.055^{b}$ | - | - |
| Dry matter | <0.001 | $17.70^{c}$ | $18.98^{b}$ | - | - | $19.23^{a}$ | - | - | $13.21^{a}$ | - | - |
| Starch | <0.001 | $81.20^{a}$ | $80.53^{a}$ | - | - | $79.59^{a}$ | - | - | $69.03^{b}$ | - | - |
| **Trial 3** | | | | | | | | | | | |
| Specific gravity | <0.001 | $1.047^{d}$ | $1.054^{bc}$ | - | $1.052^{cd}$ | - | - | - | $1.057^{abc}$ | $1.061^{a}$ | $1.059^{ab}$ |
| Dry matter | <0.001 | $12.24^{f}$ | $14.54^{e}$ | - | $16.65^{c}$ | - | - | - | $16.94^{b}$ | $16.40^{d}$ | $19.61^{a}$ |
| Starch | <0.001 | $7.8^{d}$ | $8.62^{cd}$ | - | $11.18^{c}$ | - | - | - | $10.76^{c}$ | $60.03^{a}$ | $14.99^{b}$ |
| **Trial 4** | | | | | | | | | | | |
| Specific gravity | <0.001 | $1.0513^{b}$ | $1.0693^{a}$ | - | - | - | - | $1.0673^{a}$ | - | - | - |
| Dry matter | <0.001 | $15.7^{c}$ | $18.74^{a}$ | - | - | - | - | $16.58^{b}$ | - | - | - |
| Starch | 0.110 | 10.71 | 12.77 | - | - | - | - | 11.79 | - | - | - |

Super script letters indicate significant differences between cultivars

  

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### 3.4 Discussion

Specific gravity is one of the most common methods used in the potato industry to determine the cooking or chipping quality of tubers by means of internal textural characteristics. Specific gravity determines the total solid content of a potato tuber. This is done by weighing tubers individually as is, followed by an underwater weighing where the tuber is placed in sieve and submerged in water. Specific gravity is then calculated using the following equation:

$$Specific\ gravity = \frac{Weight\ in\ air}{(Weight\ in\ air - Weight\ under\ water)}$$

(South African Department of Environment and Primary Industries, 2000)

Specific gravity measurements are performed according to this equation with no standardised scientific measure. Specific gravity is a fairly easy method to apply as it requires minimal effort and equipment.This is not a robust objective measure as there are a variety of external influences that can have a significant impact on the measure (South African Department of Environment and Primary Industries, 2000) such as water temperature, time elapsed between measurements, age of the tuber and reliability of equipment and researcher to name a few. All of these variables can influence the reliability of the method to predict classification.

Because specific gravity measurements are simpler to obtain they are more often the chosen method of evaluation. Yet, dry matter is considered a more reliable method, as it is a scientifically repeatable objective analytical method of evaluation(Fischer, et al., 2002). This may be the reason why dry matter analysis in study three delivered consistent results more so than starch and specific gravity.

Dry matter analysis is a robust standardised analytical method that is recognised internationally according to AOAC 934.01(AOAC, 2000). Dry matter is measured by drying a known wet weight of finely grated tuber, placing it in a drying oven to extract all the moisture from the flesh and then weighing it again to determine the total dry matter content(Fischer, et al., 2002).

Starch analysis on the other hand, which is commonly used as an in house method, is an intricate process that consists of many steps where errors can occur. Starch was measured by means of an enzymatic method. The enzymes used in the analysis on starch are another variable that can lead to discrepancies in the data. Enzymatic reactions can differ if the enzymes used are old or inappropriately used. Starch analysis is described as a "quite difficult" and even when completed can only deliver reasonably accurate data (Greenfield & Southgate, 2003).

Due to the regional factors affecting tuber qualities (Booysen, et al., 2013), already in 1976 it was proposed that a region specific measurements and classification systems be applied in the potato industry in the United Sates. A variety of studies were published in the American Journal of Potato Research between 1956 and 1970 on the relationship between specific gravity and dry matter (Houghland, 1966). A noteworthy amount of these studies found that the relationship between dry matter and specific gravity measures were not stable enough to be used as a standardised method (Nissen, 1967). However, limited studies were published in later years indicating no real resolution or conclusion on the matter.

In an attempt to rejuvenate the correlation charts of dry matter and specific gravity Oregon State University developed a specific gravity and dry matter reference guide which indicates the relationship between specific gravity and dry matter. The guide allows for specific gravity values that ranges from 1.055 to 1.095 with correlating dry matter values of between 16.5%-24% (Fernando & Slater, 2010). But in a study conducted in Pakistan the specific gravity of 32 different cultivars of potatoes was found to vary between 1.0343-1.1443 (Abbas, et al., 2011) which is a wider range than the average values seen in European and American potatoes. This can be due to different cultivars and agronomical methods that are used in different countries and provides motivation to test the reliability of these methods for classification of different potato cultivars in South Africa as well.

The assumption that dry matter is a linear function of specific gravity should thus not be considered scientifically validated (Sani, 1964). A tubers texture is mainly determined by the ratio of dry matter to moisture found in the tuber. The higher the dry matter content, the lower the water content, which means that such a potato has a higher specific gravity. Potatoes with a higher dry matter and low moisture content are mealy, ideal for baking, and potatoes with low dry matter and high moisture content are waxy and ideal for boiling (South African Department of Environment and Primary Industries, 2000).

In contrast with the second study, finding a weak correlation between specific gravity and dry matter, a study conducted in 1975 on 1 269 tubers in America indicated that there was a strong correlation (r=0.912) (Schippers, 1976). The Pakistan study reported a correlation of r=0.5966 (Abbas, et al., 2011). These differences in correlation may be due to different cultivars and agronomical methods that are used in different countries as well as the method used to analyse specific gravity. This discrepancy in correlations can bring the validity of superimposing specific

  

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gravity values to dry matter values into question. In many cases, these values correlate by less than 80%.

## 4 GIYCAEMIC INDEX

### 4.1 Methodology

In order to determine the validity of glycaemic index (GI) as a method to categorise potato cultivars into classes based on their ability to raise blood glucose, a three step proses was followed. Firstly to determine the GI as well as glycaemic load (GL) of any food, the amount of carbohydrate such a food contains needs to be determined. Nutrient analysis (Table 4) on selected nutrients (energy, carbohydrate (by difference), protein, fat, moisture and ash) was done at the ARC-Irene Analytical Services. The laboratory holds SANAS accreditation (Giron, 1973). Both laboratories conducted their trials according to international protocol (as recommended by an International Expert Consultation on Carbohydrates in Human Nutrition) (Food and Agriculture Organization/World Health Organization, 1998), the recommendations of the International Life Science Institute (ILSI) appointed International Committee for Standardization of GI Testing Methodology and the draft regulations of the South African Department of Health pertaining to GI testing methodology (Brouns, et al., 2005). All methods and calculations were performed according to ISO 26642(ISO 26642, 2008).

For the second step the GI of Almera potatoes, cultivated and transported under controlled conditions, were determined at two laboratories performing two trials (ISO 26642). During the first trial (Laboratory A, Trial 1), the potatoes were cooled before consumption. During the second trial (Laboratory A, Trial 2), the potatoes were consumed warm. Laboratory B performed both tests on warm samples, but used different panel members in the second trial (Laboratory B, Trial 2), than in the first trial (Laboratory B, Trial 1).This method was followed to determine whether results obtained from the different laboratories correlated with one another to evaluate the reliability of GI testing to deliver consistent results.

All the subjects used in this study performed a glucose test with either maltose or white bread (GI 100) on at least two, but preferably three different occasions in order to develop a reference value for each individual subject. The margin of error in GI determinations decreased substantially from 1 to 2 measurements of the reference food, when data from the inter-laboratory study was used by researchers (Brouns, et al., 2005).

  

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The third part step was to compare the results obtained from the glycaemic tests done at the different laboratories to international data to determine whether the values are internationally comparable correlated.

## 4.2 Results

**In Table 4 the results of the first step of the study shows selected nutritional values for the Almera potato. The carbohydrate value was used to determine the GL of the samples. GL was calculated according to the set equation:**

$$\boldsymbol{Glycaemic\ Load = Charbohydrates \times \frac{Glycaemic\ Index}{100}}$$

**(Foster-Powell, et al., 2002)**

**Table 4: The nutritional composition of raw Almera potatoes (g/100g)**

| | Moisture (g) | Fat (g) | Protein (g) | Carbohydrates (g) | Fibre (g) | Ash (g) |
|---|---|---|---|---|---|---|
| **Almera** (raw with skin)* | 86.3 | 0.07 | 2.24 | 9.46 | 1.02 | 0.93 |
| Potatoes (raw with skin)^ | 80.2 | 0.10 | 1.50 | 15.9 | 1.50 | 0.90 |

* Own data obtained at ARC-Irene Analytical Services
^ Food Composition Database, 1999

The GI and GL values obtained from the second step in the study is shown in Table 5. The CI indicates that the researcher can be 95 % confident that the GI value of the specific product will lie between the bottom and the top values presented. The mean GI value of Almera potatoes was found to be 43 and an average GL value of 4.07, which classifies this product as a low GI food (GI ≤ 55). Laboratory A, Trial 1,the GI value for Almera potato were between 33 and 52. For Laboratory A, Trial 2 the GI values were between 86 and 35 with an average of 63 and a GL value of 5.96, which classifies this product as a medium GI food (GI 56 -69).

Laboratory B, Trial 2 had an average GI of 84 and Trial 2 had an average GI of 96 and both trials had a standard deviation of 21, which shows noteworthy differences between the different subjects. These GI values place the Almera potato in the high GI class (70>). These values from laboratory B compared with the value for baked potatoes in the South African Glycaemic Index and Load Guideat a GI of 85 (high GI) (Steenkamp & Delport, 2005).

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The final step in the study was to compare the data obtained from the two laboratories trials with international data. For this part of the study the South African values were compared to that of the Sydney University Glycemic Index Research Service (SUGIRS) (Atkins & Brand-Miller, 2006) (Figure 1).

Difference were seen in the GI values between both laboratories and all four the trials. It can be clearly seen that the GI values from Laboratory B were significantly higher than the values obtained from Laboratory A (Table 5 and Figure 1). The data obtained in the second trial at Laboratory A also produced results which were similar to the result published on the electronic database of the Australian GI website(Glycemic Index, 2010) (Figure 1).

**Table 5: Comparison of the GI and GL values for Almera potatoes from two different laboratories**

| | Laboratory A | | | | Laboratory B | | | |
|---|---|---|---|---|---|---|---|---|
| | Trial 1 (cooled potatoes) | | Trial 2 (warm potatoes) | | Trial 1 (warm potatoes) | | Trial 2 (warm potatoes) | |
| **Subjects** | **GI** | **GL** | **GI** | **GL** | **GI** | **GL** | **GI** | **GL** |
| GI Mean | 43 | 4.07 | 63 | 5.96 | 84 | 7.95 | 96 | 9.08 |
| SD | 14 | 1.32 | 18 | 1.70 | 21 | 1.99 | 21 | 1.99 |
| 95 % CI (lower) | 33 | 3.12 | 50 | 4.73 | - | - | - | - |
| 95 % CI (higher) | 52 | 4.92 | 76 | 7.19 | - | - | - | - |
| Subject 1 | 46 | 4.35 | 51 | 4.82 | 125 | 11.83 | 98 | 9.27 |
| Subject 2 | 28 | 2.65 | 81 | 7.66 | 99 | 9.37 | 121 | 11.45 |
| Subject 3 | 29 | 2.74 | 85 | 8.04 | 126 | 11.92 | 130 | 12.30 |
| Subject 4 | 47 | 4.45 | 61 | 5.77 | 67 | 6.34 | 75 | 7.10 |
| Subject 5 | 54 | 5.11 | 86 | 8.14 | 51 | 4.82 | 77 | 7.28 |
| Subject 6 | 53* | 5.01* | 45* | 4.26* | 72 | 6.81 | 98 | 9.27 |
| Subject 7 | 61* | 5.77* | 35* | 3.31* | 98 | 9.27 | 97 | 9.18 |
| Subject 8 | 27 | 2.55 | 46 | 4.35 | 85 | 8.04 | 79 | 7.47 |
| Subject 9 | 55 | 5.20 | 64 | 6.05 | 86 | 8.14 | 137 | 12.96 |
| Subject 10 | 21* | 1.99* | 76* | 7.19* | 57 | 5.39 | 74 | 7.00 |
| Subject 11 | - | - | - | - | 60 | 5.68 | 83 | 7.85 |
| Subject 12 | - | - | - | - | 80 | 7.57 | 87 | 8.23 |

  

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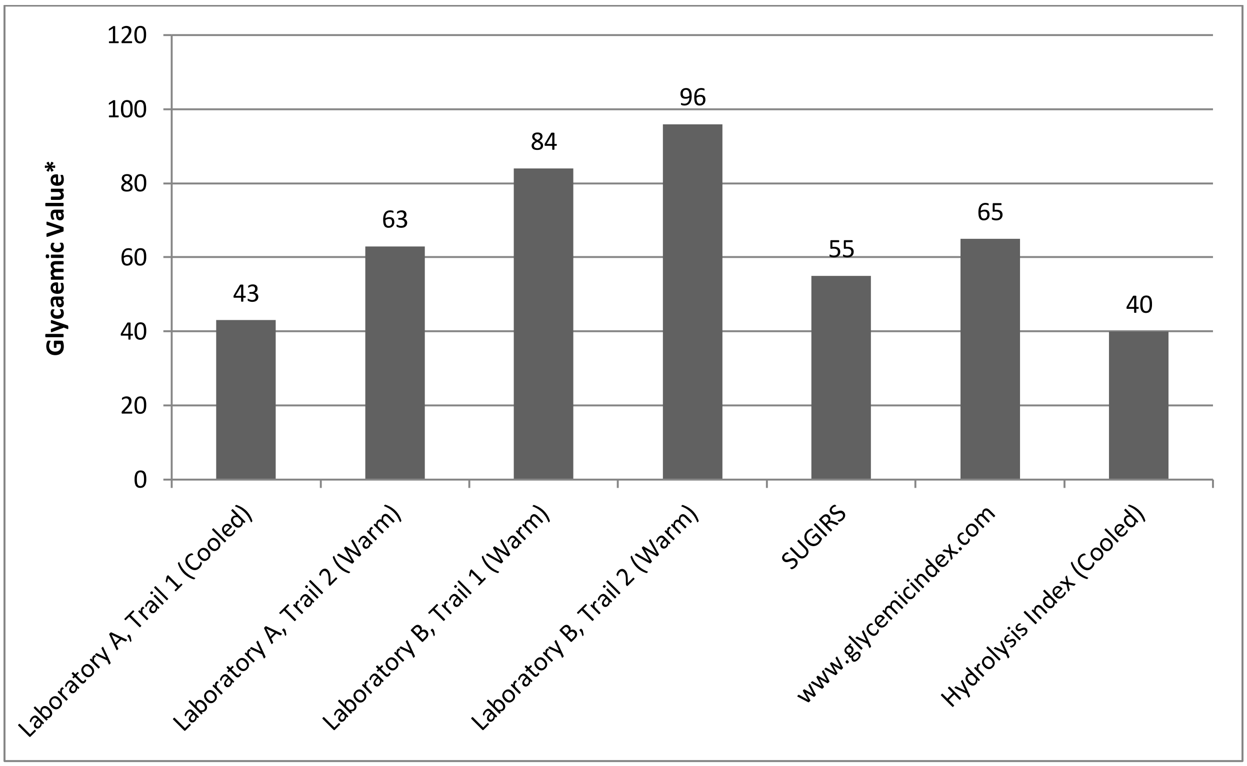
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Subject 13 | - | - | - | - | 82 | 7.76 | 90 | 8.51 |
| Subject 14 | - | - | - | - | - | - | 70 | 6.62 |

*Non-Insulin Dependent Diabetes Mellitus (NIDDM)




*A food with a glycaemic index value greater than or equal to 70 is considered to have a high GI, lower than or equal to 55 is considered to have a low GI, and a value between 70 and 55 (or from 56 – 69) is classified as an Intermediate GI food.

**Figure 1: GI values for cooked Almera potatoes obtained**

## 4.3 Discussion

Various factors influence the GI of a food product including product characteristics such as cultivar, growing conditions, preparation method, etc. Furthermore, the method used to determine GI could also impact significantly on the GI reading which is obtained.

Glycaemic index is expressed as as a percentage of the response to 50 g carbohydrate of a standard (reference) food taken by the same subject, on a different day. This reference food is usually either white bread or maltose or even both. Until recently the effect of food on blood sugar levels was determined by carbohydrates in the food. Glycaemic index is seen as a more reliable method to determine the effect of food on blood glucose levels. Glycaemic index is expressed in between 1 and 100 depending on the rate of carbohydrate absorption (Cummings & Stephan, 2007). The lower the rise of blood glucose level the lower the glycaemic index of a food(Food and Agriculture Organization/World Health Organization, 1998).

There are a few factors that have an influence on GI values obtained from human subjects. Firstly it is essential to note that human subjects vary, however, this is taken into consideration as the effect of the food on blood glucose values is compared to the effect of a reference food, e.g. glucose or white bread on blood glucose values in the same individual. Secondly, many factors, including emotional and stress factors, which cannot be controlled, may also play a significant role in influencing glycaemic response (Cummings & Stephan, 2007). It thus becomes important to ensure that the person is subject to the same conditions when performing the reference test (i.e. glucose), than when testing a specific food.

There is also a large variability in glycaemic response between different individuals (Frost & Dornhurst, 2000). In a study which included healthy individuals, non-insulin treated Non-Insulin Dependent Diabetes (NIDDM), insulin-treated NIDDM and Insulin Dependent Diabetes (IDDM) subjects, it was found that the coefficient variation (CV) values between individuals from each group were 26 %, 34 %, 23 % and 34 % respectively (Wolver, et al., 2008). This adds up to a mean inter-individual CV of 29 %.

Earlier work by Coulston noted that by expressing glycaemic response of a test food as a comparison of the response to a reference food, the variation in GI that occurs for age, sex, body composition, ethnicity and medical conditions should be accounted for (Coulston, et al., 1984). A similar study (Jenkins, et al., 1981) found that by expressing glycaemic results this way reduced inter-individual CV from 40 % to 10 %.

Although expressing values as a percentage compared to response to a control food reduced inter-individual variation, the GI measurements of the same food have been seen to vary greatly between individuals (Frost & Dornhurst, 2000). Although GI was calculated as stated above, a later study found (Matthan, et al., 2010) that variability in GI values can still in part be explained by differences in age. Another study (Hollenbeck, et al., 1986) found that the GI values of lentils range between 23 and 70 for different subjects. It is furthermore suggested that this variation in results obtained between individuals can be reduced when both the food to be tested and the control food are measured in triplicate by each panellist (Frost & Dornhurst, 2000).However, this is not done in practise, as the costs involved would be exponential.

In this study, as a high degree of variation was observed between individuals within the initial GI test at Laboratory B (SD > 20), it was prudently decided to repeat the analysis in both laboratories. However, including an additional 14 individuals in the second Laboratory 2 trial did not alter the GI of the test food in such a way as to change the GI category into which the food would be classified.

The Sydney University Glycemic Index Research Service (SUGIRS) was established in 1995 to provide a commercial GI testing laboratory for the international food industry. According to Dr Alan Barkley of SUGIRS, their laboratory tested the GI of the Almera potato cultivar on eight different occasions. The results from these trials varied from 40 to 69, with a mean GI value of 55. For each test, the potatoes used for the samples were grown under slightly different conditions. In Dr Barkley's opinion the Almera cultivar, when grown under the correct conditions and cooked appropriately, would have a low GI (Barkley, 2010). The values obtained from SUGIRS differed to those seen in this paper of 43 for Laboratory A, Trial 1; 63 for Laboratory A, Trial 2; 84 for Laboratory B, Trial 1 and 96 for Laboratory B, Trial 2.

Due to all the factors that can have an influence when measuring the glycaemic index of food *in vivo* the reliability of this method to class potatoes into categories warrants further investigation as reliability seems limited.

## 5 CONCLUSION

From study one, two and three it can be concluded that dry matter, starch and specific gravity are objective measure that can be used to classify potatoes into textural classes. However, specific gravity did not deliver consistent, correlating results. Dry matter is the most robust method and showed to be the most reliable method to correlate with the internal textural properties of potato tubers.

Significant differences were found between GI values and more specifically, GI categories (low, medium and high GI), obtained from different laboratories executing *in vivo* analysis on the Almera potatoes. This can leads to questions about the reliability of the method as well as the preciseness with which it is performed at the different laboratories.

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