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# Physico-chemical properties of potato starches

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ABSTRACT

Starches were isolated and characterised from 10 potato cultivars grown under the same conditions (with a commercial starch for reference). The chemical composition revealed some differences amongst the starches with protein ranging from 0.30% to 0.34%, amylose 25.2% to 29.1% and phosphorus 52.6–66.2 mg 100 $g^{-1}$. High performance size-exclusion chromatography (HPSEC) fractionation of isoamylase debranched amylopectin showed that the amylopectin molecules were less branched and consisted of more B1, but less A-chains, than cereal starches. Gelatinisation onset ($T_o$), peak ($T_p$) and conclusion ($T_c$) temperatures of the native potato starches ranged from 58.7 to 62.5 °C, 62.5 to 66.1 °C and 68.7 to 72.3 °C, respectively, whilst the gelatinisation enthalpies ranged from 15.1 to 18.4 J $g^{-1}$. The gelatinisation temperatures of the starches increased in common with the amounts of short and intermediate sized amylopectin chains. The $^{13}C$ magic angle spinning nuclear magnetic resonance ($^{13}C$ CP-MAS NMR) and wide angle X-ray diffraction (XRD) data (30.6% ± 0.22% crystallinity on average) showed little variance amongst the samples. Particle sizing results, however, revealed more variance (20.6–30.9 μm mean diameter). Overall, these data reveal the subtleties of cultivar specific variation against a background of constant environmental conditions.



## 1. Introduction

Potatoes are the fourth most important food crop in the world after wheat, rice and maize, with a global annual production of approximately 300 million tonnes (CIP, 2008). During the last decade, potato production has declined in developed countries, but it has increased in developing and newly industrialised countries (Fao, 2006). Potatoes are grown as a vegetable for direct consumption and also as a raw material for processing into products such as: pre-formed meals, snacks, potato derivatives, starch and starch derivatives.

In terms of physical properties, potato starch is unique amongst other commercially available starches (e.g. cereal types) and has been utilised extensively in a variety of food systems (Yusuph, Tester, Ansell, & Snape, 2003). This uniqueness is due to the large granule size, purity, relatively long amylose and amylopectin chain lengths, presence of phosphate ester groups on amylopectin, ability to exchange certain cations with corresponding effects on viscosity behaviour and, ability to form thick visco-elastic gels upon heating and subsequent cooling (Vasanthan, Bergthaller, Driedger, Yeung, & Sporns, 1999). One characteristic which is very valuable for potato starches is their capacity to form clear gels when gelatinised (Adebowalea, Olu-Owolabi, Olayinkaa, & Lawalb, 2005). This is due to the phosphate ester groups and relative absence (Singh, Kaur, Sandhu, Kaur, & Nishinari, 2006) of lipid (Mishra & Rai, 2006). There are, however, considerable differences between the physico-chemical properties of potato starches obtained from different potato sources (Yusuph et al., 2003).

For many publications on potato starches it is assumed that the genotype controls the composition, structure and physical properties. However, there is much evidence in the literature (Kaur, Singh, Ezekiel, & Guraya, 2007; Noda et al., 2004; Yusuph et al., 2003) that environmental factors are just as important. The aim of the present study was to compare the physico-chemical properties of 10 potato starches extracted from different cultivars grown at the same time, and at the same site, in order to understand the origin of the potential variation with respect to the physico-chemical properties. This information could then be used as a basis for future investigations as to how genetic, environmental and processing modification could be employed to improve the functionality of the starches.

## 2. Materials and methods

### 2.1. Materials

All chemicals, reagents and solvents were of Merck Analar quality or better. Ten potato cultivars (Brodick, Kara, Desiree, Inca Sun,

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Maris Piper, Mayan Gold, Pentland Crown, Pentland Dell, Pentland Javelin and Record) were grown at the same time and under the same conditions in Perthshire at the Scottish Crop Research Institute (SCRI), Dundee, UK. The commercial potato starch (30,265) was purchased from VWR, Lutterworth.

### 2.2. Starch extraction and purification

Potatoes (free from defects) were washed, peeled lightly then liquidised in cold sodium metabisulphite: sodium chloride (1% with respect to both salts) solution. The samples were stored at 5 °C overnight (to inactivate enzymes). Using a stainless steel sieve (125 μm aperture) the starch and nonstarch materials were separated. The filtered starch liquor was centrifuged (1500*g* for 5 min at 15 °C) and the supernatant was discarded. The crude potato starches were centrifuged through 80% (w/v) caesium chloride (6000*g* for 20 min at 15 °C) as described by Tester and Morrison (1990a) to remove impurities. The purified starches were then washed extensively with excess cold distilled water (with intermittent centrifugation) at least six times. They were then rinsed with acetone twice with centrifugation (1500*g* for 5 min at 15 °C) to recover the starches. Finally, the starches were spread on glass plates and allowed to dry in air.

### 2.3. Composition

#### 2.3.1. Moisture content

Starch samples (in triplicate, ca. 100 mg) were weighed into pre-dried aluminium dishes then placed in an air forced oven for 1 h at 130 ± 3 °C to dry. The samples were removed, left in desiccators for 40 min to cool and were reweighed. The moisture content was calculated as the percentage weight loss of the sample.

#### 2.3.2. Protein content

The nitrogen content of 200 (±0.01) mg samples (in triplicate) of starch was determined by standard Kjeldahl methodology (Kirk & Sawyer, 1997) where protein content (%) was then calculated from: protein (%) = nitrogen (%) × 6.25.

#### 2.3.3. α-Glucan content

The starch (total α-glucan) content was measured according to the general method of Karkalas (1985) (with some modifications), which is based on the conversion of starch to glucose by enzymic hydrolysis. The reagents used (differing slightly from the original method due to the changes in supplier and production) were: (1) bacterial α-amylase (E.C. 3.2.1.1, Sigma A-3403 from *Bacillus licheniformis*, 500–1000 units/mg protein); (2) amyloglucosidase solution (AMG) (E.C. 3.2.1.3., Fluka 10115, from *Aspergillus niger*, 70 units/mg) where 8.57 mg was dissolved in 100 ml citrate butter (0.02 M, pH 4.6); (3) glucose oxidase – peroxidise – chromogen reagent (GOP) at pH 7.0, which was prepared by dissolving the following reagents and enzymes in deionised water (500 ml): di-sodium hydrogen orthophosphate ($Na_2HPO_4{\cdot}12H_2O$, 11.5 g), potassium dihydrogen orthophosphate ($KH_2PO_4$, 2.5 g), phenol (0.5 g), 4-aminophenazone (0.075 g), peroxidise (E.C.1.11.1.7, Type 1, Sigma P-8125, from horseradish, 0.04 g ≡ ca. 3500 units), glucose oxidase (E.C. 1.1.3.4, Sigma G-6500 from *A. niger*, 3.5 ml ≡ ca. 3500 units). Starch samples (100 ± 0.01 mg, triplicate) were solubilised using the thermostable bacterial α-amylase according to Karkalas (1985) at 85 °C and were then converted completely to glucose with amyloglucosidase at 60 °C (again according to Karkalas, 1985). Glucose was then quantified colorimetrically using the glucose-oxidase peroxidise chromogen (GOP) and a factor of 0.9 was used to convert glucose to anhydrous starch (Karkalas, 1985).

#### 2.3.4. Phosphorus content

The phosphorus content of potato starch samples (ca. 1 g weighed accurately in triplicate) were measured as phosphomolybdic blue complexes according to the American Oil Chemistry Society Official method AOCS (1987).

#### 2.3.5. Amylose content

Total amylose content was determined colorimetrically according to the method of Morrison and Laignelet (1983). The total amylose content (%) was calculated (α-glucan basis) from the blue value (defined as the absorbance of 10 mg anhydrous starch in 100 ml of diluted $I_2$–KI solution at 635 nm and 20 °C) according to the following equation:

$$\text{Amylose}\ (\%) = (28.414 \times \text{Blue Value}) - 6.218$$

#### 2.3.6. Damaged starch

The damaged starch content of the potato starches was determined by the α-amylase hydrolysis method described by Karkalas, Tester, and Morrison (1992) using the modifications described in Section 2.3.3.

### 2.4. Physical analysis of starch

#### 2.4.1. Particle sizing

Starch granules dimensions and distributions were determined using a Coulter Counter Multisizer (Coulter Electronics Ltd., UK) running 256 channels according to the methods of Morrison and Scott (1986) and Tester, Morrison, Gidley, Kirkland, and Karkalas (1994). The instrument was pre-calibrated using standard PDVP latex particles at approximately 15% of the size of the aperture (140 μm).

#### 2.4.2. Wide-angle X-ray (WAXS) characterisation

The crystallographic properties of the potato starch samples were examined according to Cheetham and Tao (1998) with a Philips PW 1840 Bragg–Brentano type parafocusing diffractometer mounted on a PW 1066/11 sealed tube X-ray generator, operating at the Cu Kα wavelength (1.5406 Å).

#### 2.4.3. Nuclear magnetic resonance (NMR) studies of starches

A Brucker DSZ 200 NMR operating at 200 MHz, with a standard Brucker 7 mm PH MASIV probe head, was used to obtain $^{13}C$ cross polarisation magic angle spinning nuclear magnetic resonance ($^{13}C$ CP-MAS/NMR) spectra and hence the amount of double helices in various starches according to the general method of Yusuph et al. (2003). Spinning rates of 5–6 kHz were used with a recycle time of 1.5 s. An average scan of 35,000 was used for each spectrum. Spectra were referenced to internal (Me4Si) and external adamantine. A contact time of 1000 s was used for all the standard spectra. Absolute amounts of double helices were estimated by calculating the area under the peaks.

#### 2.4.4. Scanning electron microscopy (SEM)

The surface and structure of the starch samples were characterised using scanning electron microscopy (SEM, Zeiss EVO 50, Massachusetts, USA). The starches were mounted directly on circular carbon stubs before being coated with palladium–gold (Pd/Au ratio 1:9) using a sputter chamber (Sputter Coater, Model sc7640, Quorum Technologies, East Sussex, UK). The following parameters were set for the instrument: accelerating voltage (kV) 5 kV, scan speed 3 with frames to average equal to 30 in order to reduce noise. Secondary electron (SE1) detection was selected to study the samples at 10 mm working distance (WD).