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Effect of particle size on the digestible energy content of field pea (*Pisum sativum* L.) in growing pigs

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ABSTRACT

A study was conducted to determine the effect of particle size of field peas on (1) the digestible energy (DE) content in growing pigs of 11 field pea varieties and (2) the kinetics of starch hydrolysis of five of these field pea varieties measured *in vitro*. Each field pea variety was ground with three screen opening-sizes: 5.4, 3.28 and 0.74 mm, resulting in a geometric mean particle size (GMPS) of 1035, 649 and 156 μm, respectively. A total of 204 growing pigs (28 ± 2 kg; 34 treatments with 6 pigs/treatment) were fed for 13 d with a basal diet composed of cereals, soybean meal and a premix or 33 pea-based diets (0.3 field pea and 0.7 basal diet) supplemented with Celite (indigestible marker). Faeces were collected by grab sampling for the last 3 d. A sequential *in vitro* hydrolysis of the starch of five of these field pea varieties at the three GMPS was conducted with pepsin (120 min) and a mixture of pancreatin, isomaltase and maltase enzymes (240 min). The DE concentration of the field peas varied from 13.38 to 16.05 MJ/kg DM ($P<0.01$). The average DE (16.1, 14.7 and 14.0 MJ/kg DM) decreased linearly with increasing GMPS ($P<0.001$). The differences in the degree of starch hydrolysis were influenced by the interaction "field pea variety × GMPS" (*e.g.* for 1035 and 649 μm of GMPS, the hydrolysis for the Acer variety was 0.90 and 0.49 *vs.* 0.47 and 0.40 for the Pekoe variety, respectively; $P<0.001$). There was a positive correlation between the DE and the degree of starch hydrolysis ($r = 0.62$; $P=0.02$). In conclusion, the DE of ground field pea varieties in growing pigs increases linearly as GMPS decreases. The differences in DE observed between field pea varieties can be explained by differences in starch hydrolysis and GMPS.

1. Introduction

The nutritional value of a feed ingredient in pigs is influenced by the size of particles obtained after grinding (Wondra et al., 1995a; Behnke, 1996; Fastinger and Mahan, 2003; Le Gall et al., 2005). Grinding improves nutrient digestibility by offering a greater surface area for contact between the digestive enzymes and the substrate (Goodband et al., 2002), after the release of the cytoplasmic content consecutive to cell wall disruption (Crevieu et al., 1997). Additionally, fine grinding is important to obtain a uniformly mixed feed (Behnke, 1996). However, too finer grinding increases power costs, feed

Abbreviations: ADFom, acid detergent fibre expressed exclusive of residual ash; BW, body weight; CTTAD, coefficient of total tract apparent digestibility; DE, digestible energy; DM, dry matter; GMPS, geometric mean particle size; aNDFom, neutral detergent fibre determined after amylase digestion and expressed exclusive of residual ash.

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handling problems, gastric ulcers and dust formation, as well as reduced production rates (Healy et al., 1994; Wondra et al., 1995a; Behnke, 1996). The optimal particle size varies according to pig category and type of ingredient (Healy et al., 1994; Wondra et al., 1995a,b). However, other authors have not found any beneficial effect of the reduction of particle size on digestibility and/or growth performance in barley (Laurinen et al., 2000) or soybean meal (Lawrence et al., 2003; Valencia et al., 2008).

Field peas are appreciated by swine nutritionists for their high digestible energy (Noblet et al., 1993; Stein et al., 2004) and lysine content (Fan et al., 1994; Castell et al., 1996; Stein et al., 2004). There is a strong relationship between the average particle size of peas and their nutritional value (Crevieu et al., 1997; Hess et al., 1998; Le Gall et al., 2005). However, little information is available regarding the possible influence of genetic origin or the environment on the response to grinding.

The aim of the present study was to determine the effect of particle size of different field pea varieties on: (1) their digestible energy (DE) content in growing pigs and (2) on their kinetics of starch digestion *in vitro*. In addition, the effect of starch hydrolysis on the DE content of peas was also studied.

2. Materials and methods

2.1. Collection, grinding and particle distribution of field pea samples

A total of 11 samples (±200 kg) of field pea that were selected to represent variations in quality, were obtained from different producers in Saskatchewan and from the Kernen experimental farm of the Crop Development Centre at the University of Saskatchewan. The samples were ground with a hammer-mill (model 160-D, Jacobson Machine Works, Minneapolis, MN, USA) with 3 different screen opening-sizes: 5.4, 3.28 and 0.74 mm. To avoid high temperatures during the grinding process, the field peas ground using the smallest screen opening-size, were first ground with a 3.28 mm-mesh screen and then with a 0.74 mm-mesh screen.

The particle size distribution after grinding was measured with a Tyler Industrial Ro-Tap testing sieve shaker (Mentor OH, USA). The sieve shaker set was equipped with 6 sieves (opening diameter of >2000; 1190; 589; 300; 150; 75 μm) and a solid metal pan. Duplicate 100 g-field pea samples were placed on the top screen and sieved for 10 min. The weight of the material remaining on each screen was used to establish the particle size distribution and the calculation of the geometric mean particle size (GMPS, d_{gw}), the log normal standard deviation (particle size uniformity, s_{gw}), the estimation of the surface area and the number of particles using the formulas proposed by ASABE (2008).

2.2. Digestibility values and energy content of field pea

A basal diet was formulated to meet all the nutritional requirements for growing pigs (NRC, 1998) (Table 1). Additionally, 33 field pea-based diets (11 varieties × 3 GMPS) that contained 700 g/kg of the basal diet and 300 g pea/kg were prepared. Animal care and use for this experiment was approved by the University of Saskatchewan Committee on Animal Care and Supply (protocol 19970019) according to the guidelines of the Canadian Council on Animal Care (CCAC, 1993). A total of 204 growing pigs of both genders (Camborough Plus females × C337 sires, PIC Canada Ltd., Winnipeg MB) with an initial body weight (BW) of 28.1 ± 2.1 kg, were kept in individual pens.

Pigs were randomly allocated to one of the diets (n = 6 per treatment, 1:1 female:male) and fed twice daily (0800 and 1500 h) in an amount corresponding to 90 g/kg metabolic BW ($BW^{0.75}$) with water provided *ad libitum*. After an adaptation period of 10 d, faeces were collected by the grab sampling method after anal stimulation, for 3 consecutive days. Faecal samples were kept at −18 °C prior to analysis. At the end of the experiment the samples were freeze-dried and ground with a lab mill (Retsch Mill ZM1, Newtown, PA, USA) passing through a 1 mm-mesh screen.

2.3. In vitro starch hydrolysis

To compare the effect of particle size on the rate of starch hydrolysis, five field pea samples from the *in vivo* experiment were chosen to represent the variation in the DE concentration obtained in that experiment (Acer, Mozart, Pekoe, Scuba, Soldem).

The enzymatic hydrolysis of the field pea samples was performed following a protocol described by Boisen and Fernandez (1997) with slight modifications. Briefly, field pea samples (500 mg) were added to a buffer solution (pH 2.0) containing pepsin (25 mg, Sigma P7000) and the mixture was incubated for 2 h at 39 °C under continuous agitation in a water-bath. A phosphate buffer saline solution (0.2 M pH 6.8) was then mixed (1/1, v/v) with the incubation medium and a mixture of pancreatin (50 mg, Sigma P7545), amyloglucosidase EC 3.2.1.3 (0.5 ml, Megazyme Int. Ltd, County Wicklow, Ireland) and invertase EC 3.2.1.3 (0.2 ml, Megazyme Int. Ltd, County Wicklow, Ireland) was added and incubated for 4 h at 39 °C. Aliquots of the solution were taken at different times to determine the starch content (0, 120, 140, 180, 240, and 360 min after pepsin hydrolysis). All field pea samples were hydrolysed in quadruplicate.

One aliquot of each sampling time was immediately treated with trichloroacetic acid to stop the enzymatic activity (75 g/L, final concentration of trichloroacetic acid). After centrifugation at 20800 × g for 10 min, the supernatant was collected to