BEHAVIOURAL ANALYSIS OF PIGS WHEN PRESENTED WITH PEA-DIETS

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ABSTRACT

The high dietary energy and acceptable digestible lysine content of field peas in comparison to soybean meal should allow for their incorporation into a wide range of diets. However, in part because of concerns over palatability, usage is limited in diets for swine. The objectives of this study were 1) to determine if peas reduce feed intake and if the pattern of consumption is indicative of a taste effect or post-ingestive feedback 2) to determine whether post-ingestive feedback plays a role in pigs' aversion to peas and 3) to determine the effect of peas on the feeding behavior of pigs. Experiment 1 examined the effect of level of pea inclusion on feed consumption. Fifty mixed gender pigs (9 weeks old) were fed 5 treatment diets (basal soy diet, 20, 40, 60% peas, canola control) in a completely randomized design for 10 days. The peas were added at the expense of wheat and soy to the basal soy diet. The canola diet was required to evaluate the response to a novel diet. No dietary effects were seen as consumption levels were not different for either 20, 40 or 60% pea diets, compared to the soy basal or canola control diets ($P = 0.16$). Experiment 2 was designed to examine post-ingestive feedback effects of peas. Twenty mixed gender pigs (8 weeks old) were fed either a 60% pea or a 10% canola diet on alternate days for 10 days. The diets were flavored with 6 gm/kg of either orange or grape Kool-Aid[TM], with 10 pigs receiving peas/grape and canola/orange, and 10 receiving peas/orange and canola/grape on alternate days. Pigs were then presented with both an orange flavored and grape flavored basal diet to assess flavor preferences. The assumption is that if a diet produced negative post-ingestive feedback it would reduce feed consumption of the associated flavor during preference testing. Pigs did not exhibit a preference for either grape over orange flavor ($P = 0.46$). This was irrespective of which diet had previously been associated with grape flavoring, as evidenced by the similarity in feed intake between the two diets (0.88 ± 0.3 and 0.89 ± 0.2 kg for pea and canola-based diets, respectively; mean $\pm$ SD, $P = 0.94$). Experiment 3 was conducted to study the short term feeding behavior of grower pigs when presented with novel pea diets. Five dietary treatments which included peas from two sources and two grinds and a control soy meal diet were used. The results of the analysis of the eating behavior showed differences in the number of meals, average meal duration and average eating time per meal ($P < 0.01$) between pea diets and soybean meal diet. The pigs fed pea diets had shorter meals than the ones on control (12.2 vs 14.7 ± 1.04 minutes) but the meals were more frequent (12.6 vs 9.3 ± 1.25). The

presence of peas affected feeding behavior but it was transitory. Moreover, the change in behavior did not affect the feed intake of the pigs. The above experiments indicate that it is possible to include high levels of peas in pig diets without affecting feed intake. In conclusion, peas used in this study did not have any palatability issues suggesting that pea inclusion in diets does not affect feed intake.

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1   INTRODUCTION

Canada is the main producer of peas in the world (FAOSTAT, 2010). Most of the production is based in Western Canada, predominantly Saskatchewan (Agriculture and Agri-Food Canada, 2008). The benefits of feeding field peas have been recognised by feed industries worldwide especially because of their high dietary energy, acceptable digestible lysine content in comparison to soybean meal and the feasibility of being incorporated into a wide range of diets. There is a substantial body of research on feeding peas to pigs, particularly in Europe. Research carried out in the 1980's in France showed the possibility of including 16 % - 24 % peas in sow diets (Gatel et al., 1988). Moreover, Grosjean et al. (1997) showed that up to 40 % peas could be included in rations for weaned pigs.

Stein et al. (2006) studied the influence of dietary field peas on pig performance, carcass quality and pork palatability and found that inclusion rates of 66 % did not cause any detrimental effects. Even though these studies suggest a high inclusion rate there are still concerns from many feed and pork producers who are reluctant to incorporate large amounts in swine rations. A survey conducted by Pulse Canada in 2007 (Pulse Canada, 2007) showed that numerous feed producers still limit their inclusion rates to 10 % or 15 % of the diet. A primary reason for their reluctance was concerns about reduced feed intake due to low palatability. A secondary concern is the heterogeneity of pea composition coupled with inconsistency of supply.

A number of studies have highlighted potential drawbacks regarding the inclusion of peas in swine diets. A German study shows that a 30 % inclusion rate of field peas in sow diets caused a negative effect on the number of pigs born suggesting that higher inclusion rates might affect sow reproductive performance (von Leitgeb et al., 1994). However, information on feeding peas to breeding stock is inconclusive and further research is necessary (Patience et al., 1995).

Studies by Mathe et al. (2003) show that the inclusion of peas at rates of 13 %, 26 % and 39 % did not cause detrimental consequences on pig growth. However the presence of peas in the feed had an effect on the eating behaviour of fattening pigs. Four different transition diets were studied in the trial and irrespective of their nature the transition diets modified various criteria of feeding behaviour such as number of visits to the feeder, eating time and rate of ingestion.

The effect of peas on feed intake was generally believed to be because of the deficiency in tryptophan which is a precursor for serotonin, a neurotransmitter involved in appetite control. A correction of this problem with tryptophan supplementation has had positive responses (Gatel and Grosjean, 1990). A decrease in feed intake cannot be currently attributed to tryptophan because the majority of diets are balanced for essential amino acids. Another possible alternative for feed refusal can be attributed to the presence of anti-nutritive factors (Huisman and Tolman, 2001; Lalles and Jansman, 1998). Although there is no scientific evidence that peas have a bad taste but the issue of taste has been mentioned many times.

Pigs are commonly used as a human model because of similarities in their digestive system. Studies by Nelson and Sanregret (1997) showed that pigs perceive and respond aversively to compounds that humans find bitter tasting. The response of pigs to the bitter tasting compounds was similar to humans but the concentration at which they responded seemed to vary. Their aversion to peas (if any) might be due to taste because research done by Heng et al. (2006a) using a trained panel of consumers showed that saponin content in peas [mainly DDMP (2,3-dihydro-2,5-dihydroxy-6-methyl-4H-pyran-4-one) saponin] seemed to be bitter in humans. This does not exclude the possibility that the aversion might be due to a negative post-ingestive effect. Aversion to a certain food can occur when it contains high amount of toxins or nutrients or nutrient imbalances (Provenza, 1995b). Post-ingestive feedback helps the animal to associate flavour with the nutrient content of the food (Forbes, 1995). If peas cause a negative feedback in pigs then this might result in a learned taste aversion for peas.

The objective of the following literature review is to provide further background information dealing with the following topics:

1) Nutritional composition and benefits of peas
2) Palatability and the factors that influence food preference

2   LITERATURE REVIEW

2.1   Peas

Peas (*Pisum sativum L.*) along with other staple protein sources like soybeans and groundnuts belong to the family *Leguminosea*. They are used as an important source of protein for both animal feed and human food (Guillaume, 1977).

2.1.1   Field pea production in Canada

The major field peas producing countries are Canada, Russia, China, India, United States and the Ukraine. The FAOSTAT (Food and Agriculture Statistics database, United Nations) 2008 shows that Canada has a production 2 times higher than its nearest competitor, Russia, making it the largest pea producer in the world (Table 2.1). Saskatchewan is the dominant producer of peas in Canada with 80 % of the total pea acreage followed by Alberta (18 %) and Manitoba (2 %) (Agriculture and Agri-Food Canada, 2008).

2.1.2   Nutritional value

2.1.2.1 Crude protein and amino acids

The crude protein content of field peas grown in Canada varies from 23.2 % to 26.2 % and these numbers are greatly affected by environmental conditions, agronomic practice and genetics (Wang and Daun, 2004). Table 2.2 shows the crude protein and amino acid content of peas compared to soybean meal. The crude protein and lysine content of peas is 46 % and 52 % respectively of that of the soybean meal (Table 2.2). Field peas contain relatively low concentrations of sulphur amino acids and tryptophan and the ileal digestibility values of these amino acids are low as well, making it necessary for producers to balance swine diets with these amino acids when incorporating peas (Stein et al., 2004).

Table 2.1: Top field pea producing countries in terms of total production in 2010

Country	Production (Metric Tonnes)
Canada	2,862,400
Russia	1,217,840
France	1,098,120
China	990,500
India	700,000
United States of America	645,050
Ukraine	452,400

FAOSTAT, 2010

Pea proteins contain high amounts of lysine [7.2-8.2 g per 16 g nitrogen (N)] and can be used as a protein and lysine supplement in cereal diets, which contain sufficient methionine and cystine but lack lysine (Khalil and Rahman, 1984; Latta and Eskin, 1980). Lysine is usually the first limiting amino acid in feed ingredients when optimizing growth of production animals (Toride, 2004). A deficiency in lysine reduces N retention and whole body protein turn-over (Salter et al., 1990; Roy et al., 2000) thereby affecting production.

2.1.2.2 Crude fat and lipids

The crude fat content of peas ranges from 15-20 g/kg DM whereas the crude fat content of soybean meal ranges from 15-28 g/kg DM (Deutsche Landwirtschafts-Gesellschaft, 1999; Jezierny et al., 2007). Predominant fatty acids in peas include linoleic acid (480 mg/g of total lipids) and oleic acid (260 mg/g of total lipids) (Bastianelli et al., 1998).

2.1.2.3 Carbohydrates and energy

The DE content of field peas is comparable to corn (Stein et al., 2004). The values for DE in field peas grown in Canada (3,862 kcal DE per kg DM) (Ziljstra et al., 1998) is also comparable to values reported for field peas in the U.S. (3,864 kcal DE per kg DM) (Stein, 2006) and Europe (3,904 kcal DE per kg DM) (Grosjean et al., 1998). The DE content of peas varies among varieties and is usually higher in sows than growing pigs (Table 2.3). The net energy of peas grown in Western Canada ranged from 2,222 to 3,084 kcal NE per kg DM (Leterme et al., 2007).

Table 2.2: The crude protein and amino acid contents of *Pisum sativum* compared to soybean meal (g/kg DM) (Adapted from Degussa, 2006)

Nutrients	*Pisum sativum*	SBM
CP	246.0	541.0
Indispensable amino acids		
Arginine	21.0	39.7
Histidine	6.1	14.4
Isoleucine	10.0	24.3
Leucine	17.4	40.9
Lysine	17.3	33.1
Methionine	2.2	7.3
Phenylalanine	11.7	27.2
Threonine	9.1	21.3
Tryptophan	2.2	7.4
Valine	11.4	25.5
Dispensable amino acids		
Alanine	10.5	23.3
Aspartic acid	28.2	62.0
Cystine	3.5	8.0
Glutamic acid	40.0	97.6
Glycine	10.6	23.0
Proline	10.2	27.5
Serine	11.5	27.3

Table 2.3: DE content (kcal/kg DM) of pea varieties in growing pigs and gestating sows (Leterme et al., 2007)

Variety	DE (growing pigs – 25kg)	DE (gestating sows)
Admiral	3380	3606
Golden	3542	3833
Cutlass	3904	3812

The carbohydrate composition of peas and soybean meal are given in table 2.4. Soybean meal has no starch while peas have a starch content of 311.3 g/kg. Important constituents of grain legumes include α – galactosides (low-weight molecular oligosaccharides), and their concentrations vary among species and cultivars (Dey, 1985; Mohamed and Rayas-Durte, 1995). The physiological effects of α – galactosides can be positive or negative depending on dosage. Lower doses have a positive effect (prebiotic effect) while high doses cause negative effects such as flatulence, reduction of dietary net energy, osmotic effects and interference with digestion of other nutrients. A dose of 3 g/day is suggested to give beneficial effects in humans (Martinez-Villaluenga et al., 2008. When compared to peas, soybean meal has a higher amount of stachyose and raffinose (Table 2.4). Freire et al. (1991) found that the apparent ileal digestibility of α – galactosides in weaned pigs when fed diets containing 45 % peas was more than 75 %.

2.1.3   Varieties

Seed cost, market and the area in which the crop is grown are the factors that influence variety selection (Pulse Production Manual, 2000). The majority of Canadian pea production is yellow peas, primarily because their yield is 10 – 15 % higher than green peas, and because green peas are subject to bleaching which reduces quality (Pulse Production Manual, 2000). The production of yellow cotyledon types is approximately 70 % of the total production with most varieties having white flowers and a semi-leafless growth habit (McVicar et al., 2009). Varieties with semi-leafless growth habit are widely used because of their high lodging tolerance and reduced vulnerability to diseases. Semi-leaf types provide less weed competition and therefore effective weed control is important (McVicar et al., 2009: Pulse Production Manual, 2000).

White flowered peas are usually preferred over dark color flowered peas because they do not contain tannins (Peyronnet et al, 1996). Tannins are anti-nutritive factors that reduce protein digestibility and provide a bitter taste to peas (Pulse Production Manual, 2000).

Research conducted by Grosjean et al. (1989) showed that the spring pea varieties have higher digestible energy and lower anti-nutritive factors for swine than winter pea varieties. Spring pea varieties are grown in Canada (Racz and Bell, 1999).

Table 2.4: Nutrient composition of *Pisum sativum* compared to soybean meal (g/kg) (Adapted from Salgado et al., 2002)

Nutrients	Soybean meal	Peas
Dry matter	883.0	874.0
Crude fat	20.7	16.7
Starch	0.0	311.3
[z] Non starch carbohydrates	387.0	389.5
Neutral Detergent Fibre	143.1	134.5
Acid Detergent Fibre	71.4	51.9
Acid Detergent Lignin	0.60	0.35
[x] Hemicellulose	71.7	82.6
[y] Cellulose	70.9	51.5
Sucrose	50.3	14.5
α – Galactosides		
Raffinose	6.9	5.3
Stachyose	43.1	23.1
Verbascose	-	13.5

(-) no values reported

z Non starch carbohydrates = organic matter – (crude protein + crude fat + starch + sucrose + α – galactosides)

[x] Hemicellulose = NDF – ADF

[y] Cellulose = ADF – ADL

Owing to limited information available on the variation in composition of Canadian field peas due to varieties and growing conditions, Wang and Duan (2004) conducted a study to determine the effect of variety and crude protein on nutrients and some anti-nutrients in field peas. Four different pea varieties, each with three levels of protein content were used in the study. The results showed that variety had a significant effect on ash, calcium, copper, cystine, sucrose, raffinose and phytic acid contents. Phytic acid is an anti-nutritive factor and therefore varieties with higher levels should be avoided. The study also revealed that phytic acid and trypsin inhibiting activity (TIA) were positively correlated to ash content suggesting that varieties with high ash content have higher levels of anti-nutritive factors. The growing conditions affected the levels of iron, magnesium, zinc, alanine, glycine, isoleucine, lysine, threonine and TIA.

2.1.4   Anti-nutritive factors

Use of grain legumes in animal nutrition is restricted and limited because of the presence of anti-nutritive factors, which might cause negative effects such as feed refusals and reduced nutrient digestibility (Huisman and Tolman, 2001; Lalles and Jansman, 1998). A study conducted by Myrie et al. (2008) with pigs show that anti-nutritive factors in feedstuffs reduce apparent ileal digestibility of amino acids by increasing endogenous amino acid losses. The anti-nutritive factors in peas include amylase inhibitors, anti-proteases (trypsin and chymo-trypsin inhibitors), haemagglutinins, phenolic acid, phytic acid, tannins and saponins (Savage and Deo, 1989; Heng et al., 2006a).

2.1.4.1 Trypsin Inhibitors

Trypsin inhibitor is present in peas, with concentrations ranging from 2.3 to 5.5 TIA (trypsin inhibiting activity) units/mg DM (dry matter) in spring varieties and 8.9 to 15.9 TIA units/mg DM in winter varieties (reviewed by Patience et al., 1995). Based on the TIA, pea cultivars are classified into four groups (a) very low activity [2-4 TIA units/mg DM], (b) low activity [4-7 TIA units/mg DM], (c) medium activity [7-10 TIA units/mg DM] and (d) fairly high activity [10-13 TIA units/mg DM] (Mikic et al., 2009). High levels of trypsin inhibitors lowers

protein efficiency ratio (weight gain divided by protein intake) and also causes pancreatic enlargement (Kakade et al., 1973). The level of trypsin inhibitors in peas varies from 10-20% of that found in soybeans (Valdebouze et al., 1980). These levels can decrease protein digestibility and growth performance (Jondreville et al., 1992; Le Drean et al., 1995).

Studies by Morrison et al. (2007) show that TIA values in peas can be reduced by heat treatment. The study showed that the higher the amount of TIA the greater the proportional reduction when treated with heat. When 13 pea varieties (winter and spring) with TIA values ranging from 2.3 to 11.8 UTI (unit of trypsin inhibited) mg/DM were fed to pigs the results showed a negative effect on ileal protein and amino acid digestibility with increasing levels of TIA (Grosjean et al., 2000). However, most commercial feed peas have TIA values lower than 4 UTI mg/DM (Grosjean et al., 1993) and the TIA values for Canadian pea varieties ranged from 1.5 to 2.7 mg/g DM (Wang and Duan, 2004).

Breeding programs effectively reduce trypsin inhibitors. Although environment may have some effect on trypsin inhibitor activity, genotype remains the most important factor in its expression (Mikic et al., 2009). The hereditary transmission of trypsin inhibitors in peas is complex and irregular, thus making the process of selection difficult (Leterme et al., 1992).

2.4.1.2 Saponins

Saponins are non-volatile, amphiphilic, surface active triterpene glycosides found in most legume seeds like peas or soybeans (Heng et al., 2006b). The most significant source of saponins in the human diet is from peas and soybean (Oakenfull, 1981). Based on their aglycone structures saponins are classified into groups A, B and E (Shiraiwa et al, 1991 a; b; Yoshiki et al., 1998). Some group B saponins may also contain a DDMP (2,3-dihydro-2,5-dihydroxy-6-methyl-4H-pyran-4-one) moiety and these are referred to as DDMP saponins (Kudou et al., 1993). Peas contain saponin B and DDMP saponin (Daveby et al., 1998). Saponin B and DDMP saponins are both bitter in taste, with DDMP saponin being significantly more bitter even at concentrations as low as 2 mg/L which is similar to the threshold level for quinine sulphate (common bitter reference compound) (Heng, 2005).

Saponins can cause anti-nutritional effects by increasing the permeability of the small intestinal mucosa cells which, in turn inhibits the active nutrient transport across the intestinal

wall (Johnsson et al., 1982). The saponin content of peas reported in different studies varies and this may be partly due to the method of extraction, as the extracting conditions overlook certain critical factors that maintain DDMP saponin stability (Heng, 2005). The saponin content in peas varies from 0.8 to 2.5 g/kg (Bishnoi and Khetarpaul, 1994; Daveby et al., 1997). The stability of DDMP saponin was studied under several conditions by (Heng et al., 2006b). The study showed that DDMP saponin was unstable at acidic and alkaline pHs, showing optimal stability at pH 7 and in water the DDMP saponin was unstable at temperatures more that 30º C. However, the presence of ethanol seemed to have a stabilising effect. These conditions have to be taken into consideration when saponins are analysed to prevent destabilising DDMP saponins thus reducing the accuracy of the analysis.

2.1.4.3 Others

Besides trypsin inhibitors and saponins, field peas may contain lectins, protease inhibitors and tannins (Gatel and Grosjean, 1990). Tannins precipitate proteins including digestive enzymes through hydrophobic interactions thereby inhibiting the absorption of nutrients (Bate-Smith et al., 1962; Hagerman and Butler, 1981). Proline rich proteins have higher affinity for tannins (Hagerman and Butler, 1981). The traditional view of tannins as only ANF is currently being challenged with research demonstrating beneficial effects of tannins such as reduced mortality from unspecific enteropathy in rabbits, caused predominantly due to the use of high protein diets (Zoccarato et al., 2008). The use of up to 0.20 % ENC (natural extract of chestnut wood rich in hydrolysable tannins) had a positive influence on growth performance in young birds with no influence on digestibility, carcass quality or N balance (Schiavone et al., 2008) showing that beneficial or anti-nutritional properties of tannins depend upon their chemical structure and dosage. The level of tannins in field peas is negligible and is 0.4 % of the amount found in grass peas (*Lathyrus sativus* – a drought resistant legume crop) (3.44 g/kg DM), and therefore shouldn't be a cause for concern (Wang et al., 1998).

Lectins and protease inhibitors can reduce feed intake and growth rate however their concentrations in field peas are low, especially in spring planted peas which are 5 to 20 times lower in anti-nutritional factors compared to other annual legumes (Anderson et al., 2002). Field peas contain between 3.8 and 7.0 mg/kg of cyanogenic glycosides. Anti-nutritional factors like

cyanogenic glycosides can be inactivated by heat but fortunately they need not be considered when peas are used as the amounts present are usually not high enough to reduce performance (Patience et al., 1995).

2.1.5   Benefits as a swine feed

Feed costs represent a significant percent of total cost in swine production systems (Molenhuis, 2010). Due to increasing feed costs producers are looking for alternate and cheaper feed ingredients to reduce the cost of production (Neill and Williams, 2010). Soybean meal is the most commonly used plant protein source in pig diets but its availability and cost is dependent on world market prices, which in turn is influenced by various factors like variation in population and economic growth, and weather conditions. Due to this reason the price and availability of SBM is volatile and a concern for pig producers encouraging them to consider locally produced feed ingredients (Gill, 1997; Jezierny et al., 2010; Trostle, 2008). The price of peas (185.00 $/tonne) is cheaper than soymeal (326.80 $/tonne) (Weekly Crop Market Review, 2012), and is preferably used in least cost feed formulations.

Experiments conducted by Castell et al. (1993) reveal that pea-canola meal blends resulted in growth rates higher than that of the control soybean meal diet showing the synergistic advantage of peas when used in combination with another protein source. Canola meal is a good source of methionine and cysteine, while peas are a superior source of lysine and energy and thereby the results seem to be better than that given by any one ingredient.

The availability of lysine (proportion of total) in the protein concentrate as assessed with pigs using food conversion efficiency on a carcass basis as the criteria for availability was high in field peas (0.93) when compared to other vegetable protein sources like cottonseed meal (0.39) and groundnut meal (0.57) but comparable to soybean meal (0.98 and 0.89) (Batterham et al, 1984).

Demand for grains for the bio-fuel industry is predicted to cause an increase in the cost of feed energy while reducing the cost of feed protein because of the production of protein rich co-products like distillers grains and distillers solubles (Stein and Lange, 2007). Peas are a good source of both energy and protein (Davis et al., 2002) and thus can be used to reduce the cost of production.

2.1.6   Recommended inclusion rates

Inclusion levels of a feed ingredient depend upon the cost, processing conditions, nutrient availability and palatability (Davis et al., 2002). Castell et al. (1996) recommended an inclusion rate of 10-15 % of raw peas in starter diets. In addition to the presence of anti-nutritive factors in peas some of the reasons for the low inclusion rate suggestion for starter diets include poorly developed digestive capacity (Cranwell, 1995) and a significant reduction in amylase and trypsin production level after weaning (Lindemann et al., 1986). The inclusion rates can be increased when the diets are balanced for limiting amino acids or if the peas are processed (Bengala Freire et al., 1989; Gatel et al., 1989). Moreover, heat treatment and enzyme supplementation improved amino acid digestibility in weaned pigs but did not improve feed intake or average daily gain (Owusu-Asiedu et al., 2002). Studies conducted by Grosjean et al. (1997) showed that field peas may be introduced at a level of 40 % in diets for weaned piglets.

The amount of peas recommended to be included in grower pig diets is higher (up to 66 %, Stein et al., 2006) and the possibility of using field peas as the sole source of supplementary protein in grower diets has been proven in trials conducted at the Agriculture Canada Research Station in Brandon (Castell et al., 1988). There was no change in carcass quality or dressing percentage when the pea diets were compared with that of a soybean control diet.

Pea inclusion rates of 56.8 % did not have any detrimental effects on the feed intake of grower pigs fed from 23 kg to 100 kg (Bell and Keith, 1990). Stein et al. (2006) proved that field peas may replace all of the soybean meal in diets fed to growing pigs without any negative effects on feed intake, carcass composition, carcass quality or pork palatability providing the diets were balanced for amino acids. Palatability of peas was not directly measured in Stein's (2006) study; however no reduction in feed intake was seen in any phase of the study. The inclusion of phytase to improve phosphorus availability and xylanase for carbohydrate digestion increased performance for growing pigs fed pea diets (Anderson et al., 2002). Mixing peas with ingredients such as canola meal increased the amount of usable peas in grower diets as the diet was then balanced for amino acids (Anderson et al., 2002).

The possibility of utilising peas as a protein source for gestating and lactating sows was studied by Gatel et al. (1987). There was no difference in birth weights, lactation growth rate, number of pigs weaned per sow per year or the number of pigs weaned per litter with the

inclusion of 16 % field peas in gestating diets and 24 % in lactating diets. A study done in Germany showed that a 30 % inclusion of field peas caused a negative effect on the number of pigs born suggesting that a higher inclusion rate might negatively affect sow reproductive performance (von Leitgeb et al., 1994). Based on these studies it is possible to conclude that field peas may be included at a level of 20 to 30 % to gestating and lactating sows.

With proper supplementation of amino acids (mainly sulphur containing amino acids and tryptophan), choosing cultivars with negligible levels of anti-nutritive factors and adapting appropriate processing techniques to remove the anti-nutritive factors, peas can be used as a good feed ingredient for pigs (Jezierny et al., 2010). However the acceptability and success of high inclusion rate of peas depend on the flavour and texture of peas (Heng, 2005), thereby making palatability an important consideration in feed/food production.

2.2   Palatability

Palatability is an important factor for the livestock industry as it affects intake and thus the growth and health of an animal. Palatability is defined in various ways. The simplest definition of palatability would be the overall acceptance and relish with which an animal consumes any given feedstuff or ration (Church, 1977). Highly palatable foods have the ability to modulate appetite control in an indirect way by influencing the choice of foods. Human studies have shown that people who were overweight gave a higher rating of pleasantness for fatty foods than lean individuals suggesting that palatability has an influence on appetite. It also shows that palatability and satiety seem to have a negative correlation where the most satiating foods were the least palatable (Holt et al., 1995; Mela and Saccheti, 1991).

Palatability is the summation of various factors and cannot be constrained to any single factor. Most definitions, however, give the idea that palatability is primarily related to taste and not to other factors. The primary reason for this seems to be the lack of an independent measure of palatability and increased intake is taken as the only evidence for both the difference in palatability and the effect of palatability on intake (Yeomans et al., 2004). This seems to be true mainly for animal studies where the most widely used method to create a difference in palatability when the nutritional content is similar, is to change the flavour of the feed (Bobroff and Kissileff, 1986; Yeomans et al., 2001). This method supports the fact that palatability

changes with the inclusion of flavour and also that it modifies behavioral responses like hunger. Another reason for believing in the "flavour affecting palatability" concept is the opioid-palatability hypothesis. This hypothesis was tested in rats where results showed that the use of opioid receptor antagonists reduced the intake of salty and sweet solutions (Cooper, 1991; Cooper and Gilbert, 1984). The blocking of the opioid receptors seemed to alter the animals liking of the food (by reducing the pleasantness) suggesting that flavour plays a vital role in palatability.

There are a few other measures of palatability for example, the perceived pleasantness of a given food, or the intent to eat (Drewnowski, 1998); all of which are related to feed intake. A review of the literature suggests that palatability cannot be measured directly and is only a hedonic evaluation of food under particular circumstances. However, researchers like Kissileff (1990) disagree with this argument stating that palatability can be objectified but appropriate standards are required. There is also wide usage of variables like taste, satiety and palatability as proxy measures for each other as they are interlinked. For example satiety is measured in terms of reduced palatability (Drewnowski, 1998).

2.2.1   Taste

Taste is one of the most important cues aiding an animal in food selection. It potentiates other cues and helps the animal differentiate harmful substances from the non-harmful ones. This phenomenon of taste enhancing has been studied in many animals including hawks (Brett et al., 1976) and mice (Palmerino et al., 1980). Taste receptors are linked to the gut defense system. The taste fibers and the visceral feedback via the vagus nerve project to the same area of the brainstem. This helps the animal form an aversion to the taste of any food that causes negative feedback. The olfactory or visual system are not primarily linked to the gut defense system but when an odour is accompanied by taste and followed by a visceral feedback from the toxin a "gate" is opened that allows the odour information to enter the gut defense system thereby causing potentiation (Garcia et al., 1985; Palmerino et al., 1980). In the hawk study taste seemed to potentiate colour and in the mice study it seemed to potentiate odour. Even though reliance on odour and colour prevents the animals from ingesting toxic substances, animals require taste to

differentiate among foods and to associate the pleasantness/unpleasantness from feeding making it the most important determiner of what to eat (Garcia, 1989).

One of the most popular models of food selection is hedyphagia where the animal selects foods based on their oro-sensory reward (Provenza and Balph, 1990). The model proposes that animals have an innate ability (as a result of evolution) to avoid tastes such as sour and bitter, as it warns them of toxins or spoilage (Bernstein, 1998; Provenza, 1995b; Provenza and Balph, 1990). Taste buds have the capacity to detect the nutritional qualities of the food consumed (Garcia, 1989). This aids the animals in selecting foods. The combination of the sense of taste and the visceral and central nervous system helps an animal in diet selection based on present and past experiences (Provenza and Villalba, 2006).

There are two different kinds of taste preference. The first is an innate taste preference. Neonates have an innate preference for sweet and reject bitter and sour. The second is an acquired taste preference which develops over time. For example, an initial rejection to salty taste during infancy changes to liking during early childhood (Cowart, 1981). Some of the factors that plays a key role in influencing preference are exposure, Pavlonian conditioning and social learning (Birch, 1993; Letarte et al., 1997; Rozin and Schulkin, 1990; Zellner et al., 1983).

Studies have shown that pigs are able to detect and avoid taste compounds that humans perceive as bitter tasting (Nelson and Sanregret, 1997) and prefer sweet taste of sugars (Kennedy and Baldwin, 1972) making them good models for human taste studies.

Even though taste plays an important part in food selection it cannot be considered as the sole factor that affects an animal's feed intake. Taste aversion learning has evolved as an adaptive measure to prevent ingestion of toxins but it can also lead to the exclusion of nutritive substances as nutritive value is not always correlated with sweetness (Forbes and Kyriazakis, 1995). In situations like this the animal has to depend on other mechanisms.

2.2.2   Post-ingestive feedback

With post-ingestive feedback the animal learns to associate flavour with the nutrient content of the food and to eat for nutrients rather than just for taste (Forbes and Kyriazakis, 1995) enabling it to consume foods that have a high nutrient profile. A study by Blair and Fitzsimons (1970) showed that the inclusion of Bitrex, a highly bitter tasting substance, showed

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no reduction in the long term intake of food by pigs. Moreover, the animal also learns to avoid foods with higher toxins or excess nutrients through post-ingestive feedback (Provenza, 1995b).

Studies with shrub blackbrush suggest that animals learn to choose food based on post-ingestive feedback (Provenza et al., 1994b). Goats presented with current season's twigs (CSG) and older growth (OG) twigs, had similar consumption on day 1 but there was a difference in intake on day 2 and day 3. The reason for this preference was because of high levels of tannin present in CSG that caused the aversion. The goats were able to learn quickly based on the aversive post-ingestive feedback. This clearly shows that animals depend on feedback effects to assess food materials. If the animal wasn't able to learn from the effects and relied on taste alone then it would have consumed more anti-nutritive factors (tannins in this case). Therefore, it is possible to say that if a bad tasting feed ingredient does not cause aversive post-ingestive effects, then preference for that ingredient may increase over time despite an initial reduction in intake because of bad taste (Provenza, 1995c).

Garcia (1989) suggests that post-ingestive feedback helps the animal associate taste with the nutritive value of the food. There is a decrease in food preference if the food causes malaise (because of excess nutrients or toxins) and conversely the preference is increased when the food causes satiety (sensation of satisfaction) (Provenza, 1995b).

Figure 2.1 shows the relationship between food preference and nutritional characteristics of food. The figure illustrates that when nutrients are consumed in excess or if there is a nutrient deficiency it causes malaise, whereas if the nutrients are eaten in correct amounts the animal is satiated.
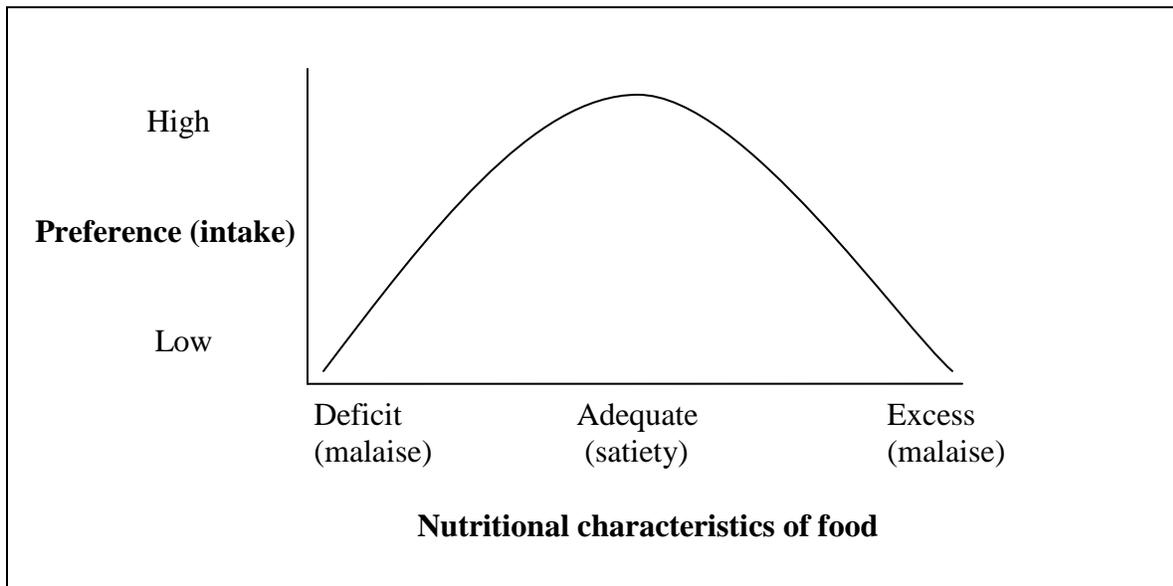
Figure 2.1: Relationship between food preference and nutritional characteristics of food (Arnold and Hill,1972).

2.2.3 Flavour-feedback interaction

It is essential for an animal to have flavour-feedback interaction because it generally cannot directly taste and smell nutrients or toxins in foods. If there is a flaw in this interaction, or if it is absent then the animal will not be able to select a nutritious diet (Forbes and Kyriazakis, 1995).

Animals are able to associate taste and post-ingestive feedback through an affective processing system (Garcia, 1989), whereby the animal is able to link both positive and negative consequences with the taste of particular foods. The animal is able to anticipate the nutritive effects of foods, and to adjust intake in accordance with nutritional needs (Booth, 1985; Rozin, 1976; Warwick et al., 1991).

The nutritional requirements of an animal determine food preference. For example, fasted humans found glucose to be pleasant before consumption, but not after consumption (Cabanac, 1971). The change in preference is caused by the interaction between taste receptors and the gastrointestinal tract. There is anatomical evidence showing a convergence of information from the gastrointestinal tract and taste in the central nervous system (CNS) (Barber and Thomas, 1987; Ricardo and Koh, 1978). This interaction between taste and post-ingestive feedback causes changes in food preference and enables the animal to choose wisely (Forbes and Kyriazakis, 1995).

2.2.4 Food Preference

Food preference is best understood as the interaction between taste and post-ingestive feedback, determined by an animal's physiological condition and a food's chemical characteristics. Through this interaction an animal learns food preference (Provenza, 1995a). Preference for a particular food can also depend on a change in liking the flavour of food or anticipated consequences from ingestion (Rozin and Zellner, 1985).

Experience plays an important role in preference and the impact is higher if it is early in the animal's life (Provenza, 1994; Provenza, 1995c). Experience is very important in an individual's life as it helps the individual to learn and to retain the consequence of behaviour, thus helping it to avoid harmful circumstances. Dietary habits of the animal are also influenced

by learning from the dam and social partners (Thorhallsdottir et al., 1990). The importance of individual experience in foraging is highlighted by Provenza et al. (1993) who showed that a lamb acquired an aversion to the food that caused a mild toxicosis on consumption. The animal refrained from consuming the food in spite of its mother's continuous consumption showing that social partners may facilitate the acquisition of foraging behaviour but continuation of the behaviour depends on the animal's reaction to the feed (Galef, 1988). Human and animal studies show that dietary habits are acquired as a result of consuming particular foods over a period of time and because of this there is an initial reluctance in the consumption of novel foods or familiar foods whose flavour has been altered (Birch and Marlin, 1982; Provenza et al., 1993). Familiarity plays a big role in food preference. When an animal gets sick after eating a meal of familiar and novel foods the animal will avoid the novel food (Revusky and Bedarf,1967) and if the animal consumes a series of only novel foods then the animal would avoid the most recently consumed novel food (Provenza et al., 1994b).

Food preference is not cognitive or rational, meaning that taste-feedback interactions happen on an automatic basis without any cognitive association. This can explain why there is a change in preference even though the feedback event occurred when the animal was anaesthetised (Bermudez-Rattoni et al., 1988; Provenza et al., 1994a; Roll and Smith, 1972). Preferences are most likely the result of both positive influences of the nutrient and negative influences of the plant secondary metabolite content of the available foods (Foley et al., 1999; Villalba et al., 2002).

In diet formulation the nutritional composition is taken into account however palatability is rarely considered. Some anti-nutritional factors are inactivated by different treatments; however, their bitter tasting properties might persist, hindering food preference and palatability (Kyriazakis et al., 1990).

2.3   Summary

The literature review suggests that there is potential for using considerably more field peas in animal nutrition and pea proteins in the food industry however it will be necessary to clarify whether pea palatability is a problem. Despite the producer's concerns that field peas have a palatability problem, it has never been demonstrated. The palatability of a feed depends

on several factors like taste, texture, odour and its integration with post-ingestive effects of nutrients and toxins present in the feed (Provenza, 1995b). A bad taste reduces feed intake as well (Vermaut et al., 1997).

2.4 Objectives

The overall objective of this study was to determine if peas cause palatability issues in pigs. The specific objectives of this series of experiments were:

1) To determine if peas reduce feed intake and if the pattern is indicative of a taste effect or post-ingestive feedback
2) To determine whether post-ingestive feedback plays a role in pigs aversion' to peas
3) To determine the effect of peas on the feeding behavior of pigs

3 EATING PATTERN OF PIGS WHEN PRESENTED WITH PEA DIETS CONTAINING DIFFERENT LEVELS OF PEAS

3.1 Introduction

Canada is the world's largest producer and exporter of yellow and green field peas. Of the 2.8 million tonnes of field peas grown in Canada in 2010, 75 % were grown in Saskatchewan, 20 % in Alberta and 5 % in Manitoba. Approximately 20 % of the field peas produced in Canada are used domestically for the feed market (www.pulsecanada.com, accessed July 28, 2010). Because of their high digestible and net energy content and relatively high content of digestible lysine, field peas have the potential to be included at a high level in swine diets. At 1.7 % (Stein et al., 2006), the lysine content of field peas is about 60 % of that found in soybean meal; and the energy content of field peas grown in Canada is 3,862 kcal DE per kg DM (Zijlstra et al., 1998) which is comparable to corn (Stein et al., 2004).

Growing pigs can perform well with 40 % field peas in their diets (Grosjean et al., 1997). In fact, Stein et al. (2006) found no detrimental effects on grower-finisher pigs' performance with an inclusion rate of 66 %. Despite this, a survey conducted by Pulse Canada in 2007 (Pulse Canada, 2007) indicated that many swine producers limit the inclusion of field peas in their diets to 10 or 15 %. The primary reason for the low inclusion rate was concerns about palatability and "reductions in" or "suppression of" feed intake. However, there are no reports in the scientific literature to validate this concern or to examine the factors in peas that may be responsible.

Taste plays a role in the diet selection of animals. It helps an animal identify and discriminate between different foods, while post-ingestive feedback helps the animal sense the consequence of food ingestion (Provenza, 1995b). Both these aide an animal choose appropriate food. A preference for a specific food is defined as an interaction between taste and post-ingestive feedback, determined by an animal's physiological condition and the chemical characteristics of the food (Provenza, 1997). Studies have shown that an animal may initially reject food with a bitter taste, but if the nutritional value of the food is balanced, then the animal may resume consumption of it after a few days (Blair and Fitzsimons, 1970).

Field peas contain various levels and types of saponins, which have a bitter taste and thus may cause an immediate aversion (Heng et al., 2006a). If peas cause an aversion, identifying the

cause of palatability issues with peas is necessary in order to rectify them. A taste issue would result in gradually increasing levels of intake at each meal (Blair and Fitzsimmons, 1970) while a post-ingestive feedback effect would start with a normal meal, a drop and then increase again as the gut adapts (Provenza et al., 1994b).

The objective of this experiment was to determine if inclusion of peas in swine diets reduced feed intake and if so, is it because of a taste effect or due to post-ingestive feedback mechanisms.

3.2   Materials and methods

3.2.1   Facilities and animals

The pigs were cared for according to the Prairie Swine Centre Inc. standard operating procedures, and the experiment was approved by the University of Saskatchewan's Animal Care Committee (#20100051) for adherence to the principles outlined in the Canadian Council of Animal Care. The study was carried out at the Prairie Swine Centre, Inc. (Saskatoon, Saskatchewan, Canada).

The pigs were housed in individual pens measuring 0.91 x 1.83 m (1.67 m^2). The pens consisted of pre-cast concrete slatted floors and solid PVC planked sides. Social contact was facilitated with a 7.5 cm wide opening on the back wall of the pens. The pigs had ad libitum access to water through nipple drinkers located at the centre of the rear wall. A single space dry feeder was placed in the front of each pen at feeding time. Thermostats were used for regulating the room temperature to 21 ℃ throughout the test period. A light period of 12 hours per day was provided.

Fifty mixed-gender growing pigs were assigned to one of five dietary treatments. Each treatment had 10 pigs with equal number of males and females. Animals used in this experiment weighed 36.2 ± 2.1 kg at the start of the experiment.

3.2.2 Diets

Diets were formulated to meet or exceed the nutrient requirements of growing pigs of this weight range (NRC, 1998). Treatments consisted of 5 different diet formulations which included a soybean meal (SBM) diet, a 10 % canola diet, a 20 % pea diet, a 40 % pea diet and a 60 % pea diet. The diets were fed in the mash form. The SBM based diet served as both the base diet and as a control which was familiar to the pigs. Pigs had been exposed to this diet for several days prior to the test. The test diets contained 20 %, 40 % and 60 % peas to assess the pigs' response to increasing levels of peas in the diet. The analysis of peas (Table 3.3) was done before being incorporated into the diets. The 10 % canola meal diet (unfamiliar control) was used in addition to the pea diets to evaluate the animals' response to novelty. The pigs used in the study were naïve to both peas and canola prior to the study. The soybean meal diet was based on wheat and soybean meal and in the test diets these ingredients were partially replaced by peas. The diets were prepared at Masterfeeds Inc, Saskatoon, Saskatchewan, Canada. Diets were supplied for a four hour period each day to allow controlled measurement of feed intake and to provide separation of meals so that post-ingestive feedback would be clearly noticed in the next clearly defined meal. The ingredient and nutrient compositions of the diets are shown in tables 3.1 and 3.2.

Table 3.1: Ingredient composition of the experimental diets used to assess palatability of peas (% as fed)

Ingredients	SBM	20% Peas	40% Peas	60% Peas	Canola
Wheat	51.45	35.64	21.84	8.19	47.57
Soymeal	30.60	26.50	20.30	15.00	24.00
Oatgroats	10.00	10.00	10.00	10.00	10.00
Fish meal	4.50	4.50	4.50	4.50	4.50
Peas	-	20.00	39.99	58.98	-
Canola meal	-	-	-	-	10.00
Mono/dical	1.00	1.00	1.00	1.00	1.00
Tallow	1.00	1.00	1.00	1.00	1.50
Limestone	0.50	0.50	0.50	0.40	0.50
Salt	0.20	0.20	0.20	0.20	0.20
[z]Masterfeeds Inc.					
Mineral mix	0.20	0.20	0.20	0.20	0.20
[z]Masterfeeds Inc.					
Vitamin mix	0.10	0.10	0.10	0.10	0.10
Lysine HCl	0.26	0.14	0.07	0.01	0.26
DL-methionine	0.02	0.05	0.10	0.15	0.01
L-threonine	0.08	0.08	0.10	0.13	0.06
L-tryptophan	-	-	-	0.05	-
Choline chloride	0.07	0.07	0.07	0.07	0.07
ZnO Zn72%	0.03	0.03	0.03	0.03	0.03

[z]Masterfeeds Inc. - 330, 103rd Street East, Saskatoon, SK, S7N 1Z1

Table 3.2: Nutrient content of the experimental diets, compared to the minimum requirements for grower pigs (as formulated)

Formulated Nutrients	[z]Minimum Requirements	SBM	Peas			Canola
			20%	40%	60%	
DE (Mcal/kg)	3.45	3.50	3.48	3.46	3.45	3.46
gDlys/Mcal (g/Mcal)	3.80	3.79	3.80	3.80	3.82	3.79
Crude protein (%)	20.90	26.99	27.00	26.39	26.05	27.03
Dlysine (%)	1.01	1.33	1.32	1.32	1.32	1.31
Calcium (%)	0.70	0.81	0.81	0.80	0.76	0.85
T phos (%)	0.60	0.77	0.76	0.75	0.74	0.82
A phos (%)	0.32	0.50	0.50	0.50	0.49	0.51
Na (%)	0.15	0.15	0.16	0.16	0.16	0.15
Cl (%)	0.15	0.30	0.27	0.26	0.25	0.31

[z]Minimum requirements - according to NRC 1998

Table 3.3: Chemical analysis of the peas used in the experiment designed to study the eating pattern of pigs when presented with pea diets containing different levels of peas

Analysis	As received	Dry matter
Moisture (%)	11.15	
Dry matter (%)	88.85	
Crude protein (%)	20.38	22.93
Acid detergent fibre (%)	10.28	11.57
Neutral detergent fibre (%)	10.75	12.09
Calcium (%)	0.10	0.11
Phosphorus (%)	0.37	0.42
Magnesium (%)	0.14	0.15
Potassium (%)	0.87	0.98
Sodium (%)	0.02	0.02
Sodium chloride (%)[z]	0.04	0.05
Copper (mg/kg)	7.90	8.89
Zinc (mg/kg)	39.25	44.17
Manganese(mg/kg)	17.99	20.25
Iron(mg/kg)	98.10	110.41

[z]calculated from sodium

3.2.3 Data collection

A health check on pigs was done twice daily in the morning and evening. The animals were given a 5-day acclimatisation period to get used to the new environment and feeding regime and were then randomly allocated to one of five dietary treatments. The animals were on the test diets for 10 days. During the acclimatisation and test period the animals were fed for four hours per day from 9 am to 1 pm. Daily feed intake and initial and final weight were measured. Feed intake was measured every day after the allotted four hour feeding period. All the measures used in this study were non-invasive.

3.2.4 Statistical Analysis

An individual pig was the experimental unit. Daily feed intake was analysed as a repeated measure using a completely randomized design one-way ANOVA model using the Proc mixed function of SAS (SAS/STAT Version 9.2, SAS Institute Inc., Cary, NC, USA). The model included treatment as a fixed effect, feed intake as a variable and day as a repeated measure. The initial and final weight were analysed using the Proc GLM procedure of SAS (SAS/STAT Version 9.2, SAS Institute Inc., Cary, NC, USA) where the individual pig was the experimental unit and the statistical model examined the fixed effects of treatment. A simple paired t-test was done in Microsoft Excel 2003 to estimate the statistical significance of intake on day 1 and day 2 within treatments. In all instances, significance was declared when $\alpha = 0.05$.

3.3 Results

Two pigs, one on the 20 %, the other on the 40 % pea diet, had to be removed from the experiment due to clinical signs of illness (postweaning multisystemic wasting syndrome) which were not related to the experiment. Their data were removed from the data-set. The remaining pigs remained healthy throughout the experiment.

There was no effect of treatment ($P = 0.16$) or treatment by day interaction on feed intake ($P = 0.16$). However, an effect of day was seen on feed intake ($P < 0.01$). Figure 3.1 shows the

results from the repeated measure analysis done on feed intake for all the treatments during the test period. The intake of all diets showed a linear increase.

When comparing feed intake on day 1 to day 2 within each treatment using paired t-test, a significant increase in intake on day 2 from day 1 was seen for soybean meal, 20 % pea, 60 % pea and canola diet ($P < 0.05$). Figure 3.2 shows the increase in intake on day 2 for all the treatments.

No differences were found among treatments in the initial ($P = 0.96$) or final body-weight ($P = 0.74$).
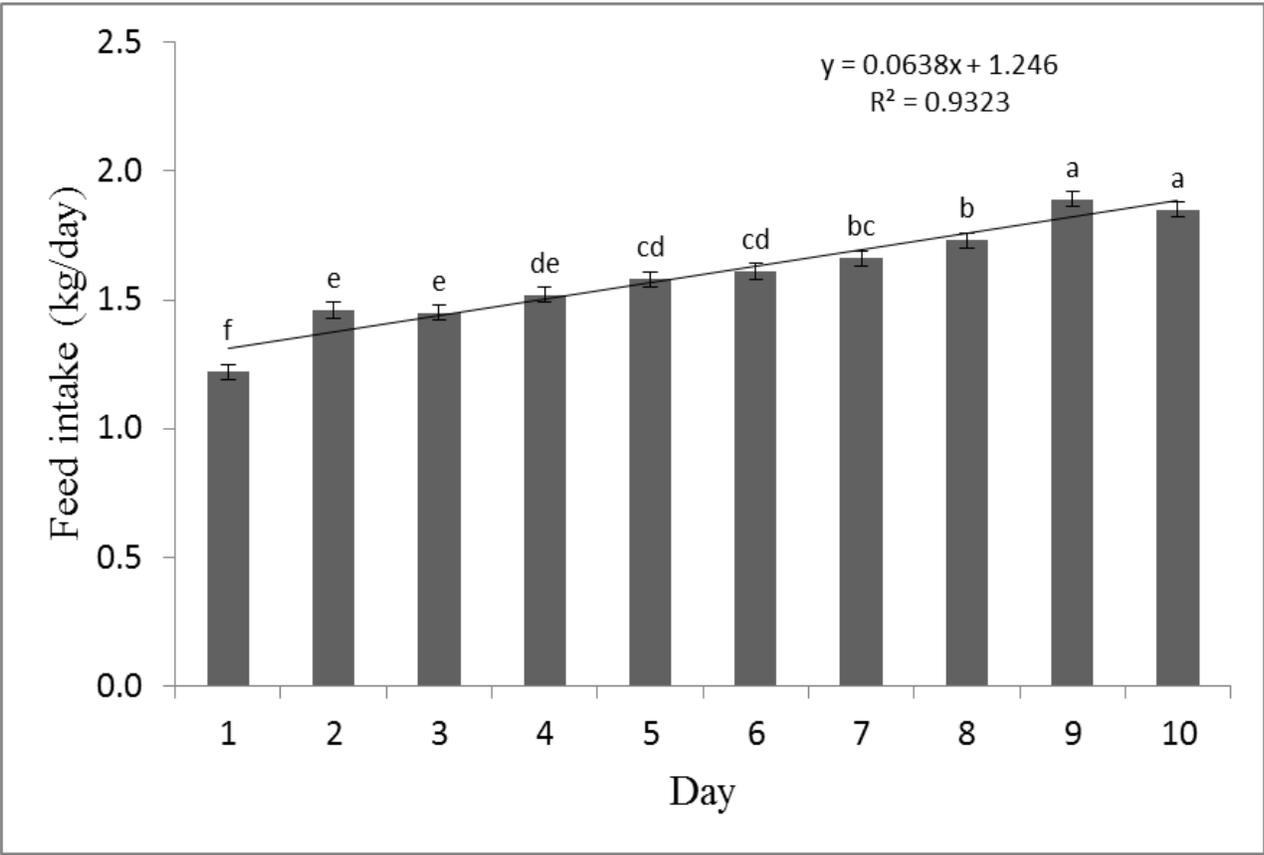
Figure 3.1: The effect of day on the average feed intake of pigs over a 10 day period on a familiar soybean meal diet, an unfamiliar diet (Canola) and three levels of pea inclusions. Bars with different superscripts mean significant differences in feed intake ($P < 0.01$; SEM = 0.03).
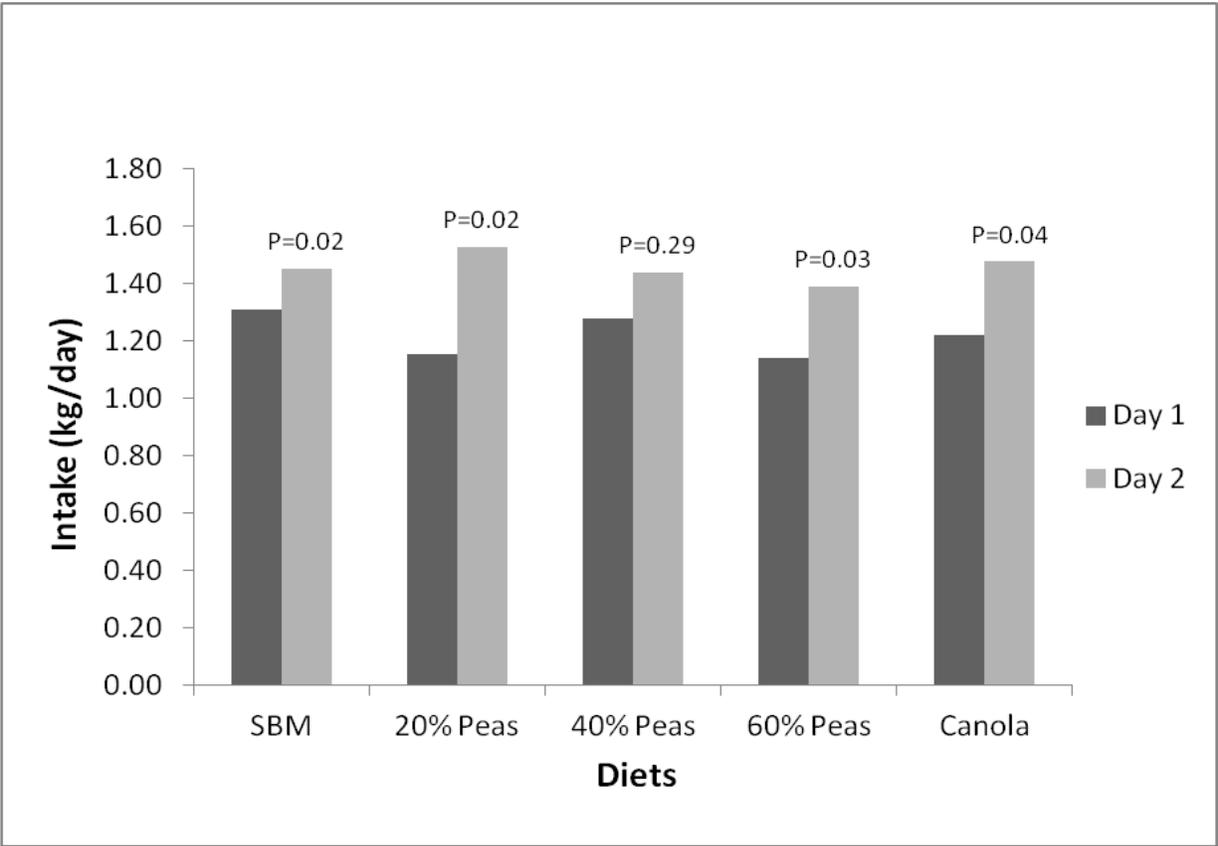
Figure 3.2: Comparison of the difference in feed intake measured for day 1 and day 2 for the five dietary treatments.

Table 3.4: The initial and final weights (mean ± SEM) of the pigs allotted to each of the five treatments

Diet	Number of pigs	Initial weight (kg)	Final weight (kg)
SBM	10	36.9 ± 0.63	47.1 ± 0.82
20 % Peas	09	37.4 ± 0.71	48.7 ± 0.98
40 % Peas	09	37.4 ± 0.78	48.2 ± 0.92
60 % Peas	10	37.7 ± 0.63	48.4 ± 1.03
Canola	10	37.5 ± 0.63	48.0 ± 0.71

3.4 Discussion

The objective of this experiment was to determine whether the inclusion of peas in diets reduced feed intake in pigs and if so was it because of innate taste avoidance (unfavourable taste) effect or a post-ingestive effect. The feed intake was similar for all the treatments in the study showing that the pigs found the pea diets to be equally palatable as the soybean meal and the canola diet. An innate taste avoidance would have resulted in a low intake on day 1 followed by an increase in subsequent meals (Blair and Fitzsimons, 1970). If peas caused negative post-ingestive feedback then a drop in feed intake would have been observed on the second day after a normal meal on the first day (Provenza et al., 1994b). No evidence of either of these effects were observed during the initial days as the consumption levels of the pea diets and the canola diet did not differ from the consumption of the control diet. Stein et al. (2004) did not find any differences in feed intake when pigs were fed pea diets along with a soybean meal control. However, it has to be noted that the inclusion rate of peas was lower (36 %) and the feed intake was not measured on a daily basis in the study by Stein et al. (2004).

Conversely, Friesen et al. (2006) showed a reduction in feed intake and growth performance when weanling pigs were fed diets containing increasing levels (0 to 30 %) of peas. There was no difference in the final weight of the pigs used in the current study. The pigs used in the current study were older than the ones used in Friesen's study which might have contributed to the difference in results between the two studies. Younger pigs have poorly developed digestive capacity (Cranwell, 1995) and significant reduction in amylase and trypsin production level immediately after weaning (the levels increase later) (Lindemann et al., 1986), which might contribute to poor digestibility of higher levels of peas.

There is no scientific evidence to show that pigs find pea taste aversive but the issue has been mentioned many times. Peas contain anti-nutritive factors like 1) saponins; a family of non-volatile, amphiphilic, surface-active triterpene glycosides widely found in legumes and 2) tannins (Lasztity et al., 1998; Wang et al., 1998). Studies by Heng et al. (2006a) showed that saponins are bitter tasting to humans. Recently it has been shown that pigs are better sensory models for humans than laboratory rodents for tastes like umami (Roura et al., 2011) suggesting that pigs perceive similar tastes as humans. These results lead to the assumption that the presence of saponins in peas might cause a taste aversion in pigs. Tannins are anti-nutritive factors that

have a bad taste as well, but their levels in field peas are negligible (Wang et al., 1998). The results from the study show that the peas used in the study did not cause taste aversion. However, it has to be noted that in the present study a commercial mix of peas was used rather than a particular variety. There is considerable variation in the amount of anti-nutritive factors among different varieties of peas (Grosjean et al., 1989; Peyronnet et al., 1996) and this could potentially cause a difference in feed intake.

The results obtained in this study might be different from the assumption of peas having a bad taste based on swine producers' concerns, and Heng's study, showing humans find saponins bitter tasting because of two possible reasons. The first one is that the peas used in the study might have had lower amounts of saponins than those used in previously conducted studies. Studies by Heng et al. (2006a) show that there is considerable variation in saponin content within pea varieties, and the pea mixture used in our study might have had lower concentrations. The second reason is that pigs might require a higher concentration of saponins for detection than humans. Bitter taste is perceived in mammals by a large family of putative mammalian taste receptors known as T2Rs (Chandrashekar et al., 2000). However there is considerable variation in the T2R gene repertoire among mammals in terms of gene number and protein sequences (Shi and Zhang, 2006) creating a difference in how different species perceive various compounds.

Neophobia, an aversion to consuming novel diets, is commonly seen in herbivores and omnivores (Rozin and Vollmecke, 1986; Chapple and Lynch, 1986). This is a mechanism by which animals avoid eating toxic substances (Rozin and Vollmecke, 1986) and has been a topic of interest as reluctance to ingest new diets can cause health and welfare concerns (Bolhuis et al., 2009). Several studies have been conducted to find solutions to this issue (Oostindjer et al., 2011; Launchbaugh et al., 1997). In our study we did not see a reduction in feed intake when the pigs were presented with novel pea or canola-containing diets. These results are similar to the results obtained by Cloutier et al. (2006) in which the authors found no evidence of neophobia in sows fed novel alcohol and dextrose diets. A possible reason for the results obtained can be attributed to the use of grower pigs, which unlike the weanlings used in the study of Friesen et al. (2006) had previous exposure to other novel foods prior to our experiment.

Animals are able to learn quickly from post-ingestive feedback mechanisms, as shown in studies by Provenza et al. (1994b) in which goats learned to reduce their intake of a diet containing tannins (an anti-nutritive factor) after consuming small amounts (44 g) when two

novel diets were presented. This helps an animal refrain from ingesting high amounts of toxic substances. In the present study, feed intake increased from day 1 to day 2 suggesting that the peas did not cause a negative post-ingestive feedback. A negative post-ingestive feedback would have resulted in lower intakes on the second day. The diets were all balanced for their nutritional content so that a nutrient imbalance wouldn't cause a reduced intake and the underlying reason for aversion to peas (if any) can be identified. Overall, the results of our study suggest that the peas used in our study did not have palatability issues and they can be included in high amounts to replace all of the soybean meal as suggested by Stein et al. (2006).

The results in this experiment indicate that the peas do not cause an aversion or reduce feed intake in pigs due to a taste or post-ingestive effect. These results will be very useful to pork and feed producers. This will encourage them to include a higher percentage of peas in their diets which may reduce feed production costs. Further research is recommended with different varieties of Canadian peas.

4 USE OF FLAVOUR ASSOCIATION AND PREFERENCE TESTS TO ASSESS THE PALATABILITY OF PEA DIETS

4.1 Introduction

With an annual production ranging from 3 to 3.7 million tonnes, field peas constitute a major source of income for farmers in Western Canada. Because of their high content of digestible energy and certain essential amino acids, field peas constitute an excellent feed ingredient for swine. A recent survey among Canadian farmers showed that they were reluctant to use high levels of peas in swine diets mainly because of concerns about taste and feed intake (Pulse Canada, 2007). Informal contacts with feed producers and pork producers (mainly from Hutterite colonies) reveal that the usage of peas in their swine diets is considerably lower than the amounts recommended. Reduced feed intake is often cited as the reason but to our knowledge the underlying reason for lower feed intake hasn't been studied in detail.

Garcia (1989) suggests post-ingestive feedback calibrates taste in accord with a food's homeostatic utility which suggests that food preference is formed by a combination of taste and post-ingestive interaction. An animal learns to associate taste with the nutritive value of the food. There is a decrease in food preference if the food causes malaise (because of nutrient imbalance or toxins) and conversely the preference is increased when the food causes satiety (sensation of satisfaction) (Provenza, 1995b). Burritt and Provenza (1992) explored the role of taste and post-ingestive feedback mechanisms in lambs. The lambs were trained to associate a specific flavour with either a high calorie or low calorie solution. When a preference test was conducted the animals chose the flavour associated with the high calorie solution showing that animals modify their diet choices by associating flavours with post-ingestive consequences.

The objective of this experiment was to study the post-ingestive effects of peas in pigs by associating a flavour with the diets. A positive post-ingestive feedback would result in an increased preference for the flavour associated with the pea diets whereas a negative feedback would result in a reduced preference as the animals learn to associate the flavour of the diet with the effects.

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4.2 Materials and methods

4.2.1 Facilities and animals

The experiment was conducted at the Prairie Swine Centre in a room consisting of 76 pens, 0.91 x 1.83 m (1.67 m^2), and pigs housed individually. The pens consisted of pre-cast concrete slatted floors and solid PVC planked sides. To prevent isolation stress the pens have a 7.5cm wide opening on the back wall to allow social contact. Unlimited water supply was provided through nipple drinkers positioned at the centre of the rear wall. Single space dry feeders were placed in the front of each pen during feeding time. Thermostats were used for regulating the temperature at 23.5 ℃ throughout the test period. A light period of 12 hours per day was provided.

Animals used in the experiment weighed 23.25 ± 1.3 (mean ± SD) kg. Twenty pigs of mixed gender were used. Feeding pigs daily meals rather than giving them continuous access to feed was the only stressor imposed, and it was not expected to cause negative effects. If pigs refused to consume a specific treatment diet for three days they were taken off the treatment diet and provided the control diet. This research protocol was approved by the University of Saskatchewan's Animal Care Committee (#20100051), which is regulated by the Canadian Council on Animal Care.

4.2.2 Diets

Three different diets were used; a basal familiar soybean meal diet (SBM) and two unfamiliar diets, one based on canola meal the other, based on peas. The pigs used in the study were naïve to both peas and canola prior to the study. The SBM diet was used during the acclimatization period and hence referred to as a familiar diet. The analysis of peas (Table 4.3) was done before being incorporated into the diets. All the diets used were formulated to meet or exceed the nutrient requirements of the grower pig (NRC, 1998). The diets were prepared at Masterfeeds Inc., Saskatoon. Diets were fed ad libitum for a 4 hour period each day to allow controlled measurement of feed intake. Moreover, another reason for short meals was to provide

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separation of meals so that post-ingestive feedback would be clearly noticed in the next meal. Ingredient and nutrient composition of the diets are shown in table 4.1 and 4.2, respectively.

Table 4.1: Ingredient composition of the three experimental diets (% as fed) used in the study

Ingredients	SBM	60 % Peas	Canola
Wheat	51.45	8.19	47.57
Soymeal	30.60	15.00	24.00
Oatgroats	10.00	10.00	10.00
Fish meal	4.50	4.50	4.50
Peas	-	58.98	-
Canola	-	-	10.00
Mono/dical	1.00	1.00	1.00
Tallow	1.00	1.00	1.50
Limestone	0.50	0.40	0.50
Salt	0.20	0.20	0.20
[z]Masterfeeds Inc. Mineral mix	0.20	0.20	0.20
[z]Masterfeeds Inc. Vitamin mix	0.10	0.10	0.10
Lysine HCl	0.26	0.01	0.26
DL-methionine	0.02	0.15	0.01
L-threonine	0.08	0.13	0.06
L-tryptophan	-	0.05	-
Choline chloride	0.07	0.07	0.07
ZnO Zn72 %	0.03	0.03	0.03

[z]Masterfeeds Inc. - 330, 103rd Street East, Saskatoon, SK, S7N 1Z1

Table 4.2: Nutrient content of the three experimental diets used in the study, compared to the minimum requirements for grower pigs

Formulated Nutrients	[z]Minimum Requirement	SBM	60 %peas	Canola
DE (Mcal/kg)	3.45	3.50	3.45	3.46
gDlys/Mcal (g/Mcal)	3.80	3.79	3.82	3.79
Crude protein (%)	20.90	26.99	26.05	27.03
Dlysine (%)	1.01	1.33	1.32	1.31
Calcium (%)	0.70	0.81	0.76	0.85
T phos (%)	0.60	0.77	0.74	0.82
A phos (%)	0.32	0.50	0.49	0.51
Na (%)	0.15	0.15	0.16	0.15
Cl (%)	0.15	0.30	0.25	0.31

[z]Minimum requirement - according to NRC 1998

Table 4.3: Chemical analysis of the peas used in the experiment using flavour association and preference tests to assess the palatability of pea diets

Analysis	As received	Dry matter
Moisture (%)	11.15	
Dry matter (%)	88.85	
Crude protein (%)	20.38	22.93
Acid detergent fibre (%)	10.28	11.57
Neutral detergent fibre (%)	10.75	12.09
Calcium (%)	0.10	0.11
Phosphorus (%)	0.37	0.42
Magnesium (%)	0.14	0.15
Potassium (%)	0.87	0.98
Sodium (%)	0.02	0.02
Sodium chloride (%)[z]	0.04	0.05
Copper (mg/kg)	7.90	8.89
Zinc (mg/kg)	39.25	44.17
Manganese(mg/kg)	17.99	20.25
Iron(mg/kg)	98.10	110.41

[z]calculated from sodium

4.2.3   Data collection

A preliminary experiment (described in Appendix) was conducted to select two flavours that resulted in the most similar intake among a group of naïve pigs. Based on the preliminary experiment, grape and orange flavours were chosen.

Prior to the test period the animals were provided a 5 day period for acclimatization to the environmental conditions and feeding regime. During this period the animals were provided the SBM diet for four hours per day. The methodology used in the experiment is similar to the one used by Burritt and Provenza (1992) to assess learning in animals based on postingestive consequences.

Training period

After the acclimatization period the pigs were trained, over a 10-day period, to associate a unique flavour (grape or orange) with each of the unfamiliar diets (Figure 4.1). Diets were flavoured by the addition of 6 g/kg of grape or orange Kool-Aid^{TM} immediately prior to feeding. Half of the pigs received a pea diet flavoured with orange and a canola diet flavoured with grape on alternate days of the training period. The remaining pigs received a pea diet flavoured with grape and a canola diet flavoured with orange on alternate days; resulting in four dietary treatments. Treatments were assigned in pairs and fed on alternate days; such that 10 pigs alternated between the pea/grape and canola/orange diets and a further 10 pigs alternated between the pea/orange and canola/grape treatments. The objective of alternating the diets every other day was to ensure that the digestive system of the animal did not get adapted to the feed. Moreover, the flavours assigned to similar diets between the groups were reversed to eliminate a flavor effect.

Preference test

A 5-day "wash-out" period following the experimental period during which time all animals received the SBM control diet. Subsequently, a preference test was carried out. Pigs were simultaneously offered both grape and orange-flavored SBM control diet (2 kg each) and intakes of each were determined. The feed intake was measured daily throughout the experimental period.

4.2.4   Statistical Analysis

The feed intake data during the preference test were analysed as a completely randomized design with the Proc GLM procedure of SAS (SAS/STAT Version 9.2, SAS Institute Inc., Cary, NC, USA). The individual pig was the experimental unit and the statistical model examined the fixed effects of treatment on feed intake. Two separate analyses were done. One analysis was done to test the effect of flavour, regardless of the association, on intake. A second analysis was done to compare intake of the pea associated flavour versus the canola associated flavor. The intake was expressed in kilograms (kg). In all instances, significance was declared when $\alpha = 0.05$.

4.3   Results

All the pigs in the experiment remained healthy and no pigs were removed from the experiment.

Training period

Pigs consumed an average of 1.19 ± 0.19 kg/d of flavoured pea diet and 1.15 ± 0.18 kg/d (mean ± SD) of flavoured canola diet during the 10 days of conditioning.

Pigs	Acclimatization period	Training period – to associate flavour with diet	Washout period	Preference test
n=10				
n=10				
	7 days	10 days	5 days	1 day
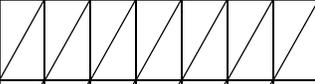
◻ Soybean meal diet

■ Orange flavoured pea/canola diet

☐ Grape flavoured pea/canola diet

▦ Orange flavoured soybean meal diet

▨ Grape flavoured soybean meal diet

Figure 4.1: Schematic representation of the timeline for the experiment

Preference test

When considering the consumption based on flavour alone, the intake of grape flavoured diets was not significantly different from the intake of orange flavoured diets ($P = 0.46$). Figure 4.2 shows the intake of diets during the preference test based on flavour.

When considering the consumption based on flavour associated with diet, there was no difference in intake between the flavour associated with pea diet and the flavour associated with canola diet ($P = 0.94$). Figure 4.3 shows the intake of diets during the preference test based on flavour association to diet.
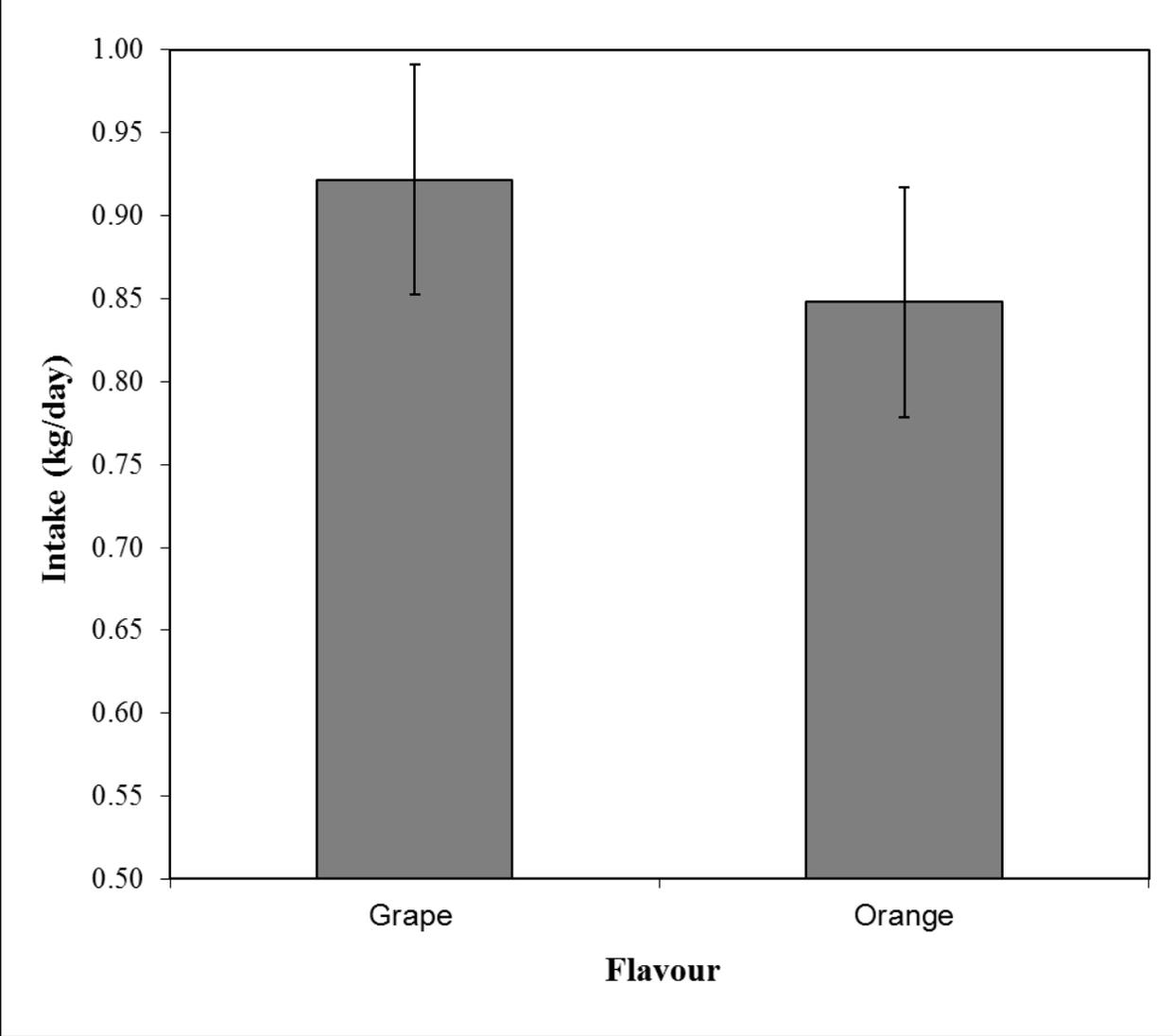
Figure 4.2: Feed intake of soybean diet flavoured with orange or grape during the preference test $(P = 0.46$; SEM = 0.07).
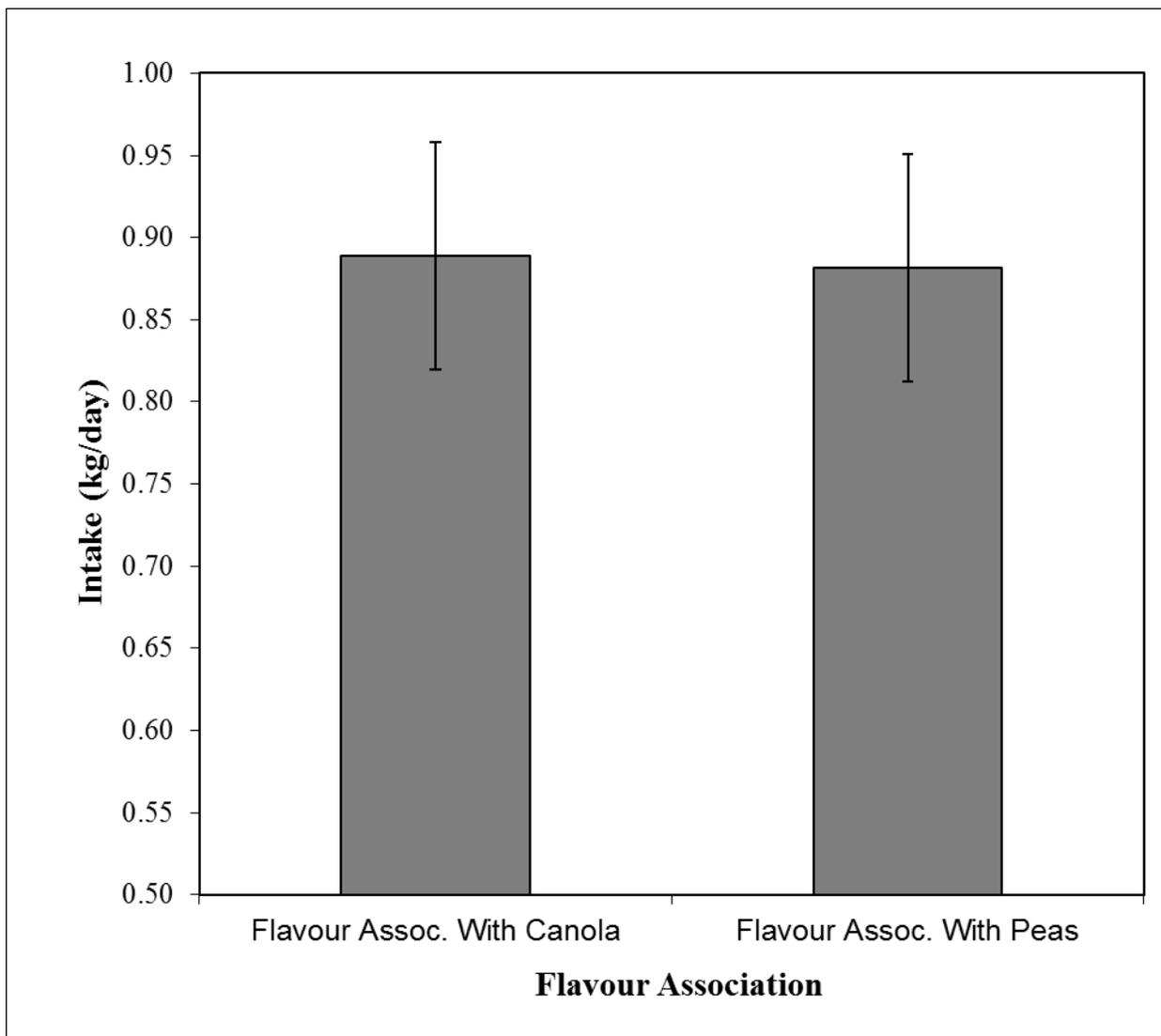
Figure 4.3: Feed intake of SBM diets flavoured with orange and grape by pigs that have formed an association of orange or grape flavour with pea or canola (P = 0.94; SEM = 0.07).

4.4   Discussion

The study by Burritt and Provenza (1992) showed that animals learn to differentiate foods based on post-ingestive feedback. Lambs used in their study preferred to consume foods with positive post-ingestive consequences (in this case energy). Their results are supported by others (Hayward, 1983; Villalba and Provenza, 2000). Conversely, animals avoid consuming foods that cause negative post ingestive feedback (Bernstein, 1994; Provenza, 1996). Studies by Kyriazakis et al. (1990) showed that pigs were able to choose a balanced diet when given a choice between foods varying in protein content. Based on the results of these studies, it is clear that animals associate post-ingestive consequences with flavours and the preference for a flavour reflects their preference for the associated food and its post-ingestive effects.

Our expected outcomes were based on previous studies (Bernstein, 1994; Burritt and Provenza, 1992; Hayward, 1983; Provenza, 1996; Villalba and Provenza, 2000). We hypothesized that if peas cause a negative post-ingestive feedback during the training period then the pigs will prefer the flavour associated with the canola diet during the preference test. Conversely if the pigs prefer the flavour associated with peas or consume equal amounts of both flavoured diets during the preference test then peas do not cause negative post-ingestive feedback. During the training period the animals would make an association for the flavour with the diet through learning (Kennedy and Baldwin, 1972).

Results from the study show that pigs ate both the orange and grape flavoured diets in equal amounts during the preference test, which indicates that there was no preference for these flavours. Moreover, no difference in preference for flavour associated with diet intake was seen. If peas contained anti-nutritive factors or toxins that cause aversion, the pigs should have avoided ingesting high amounts of the flavour associated with the pea diet (Provenza, 1996; Bernstein, 1994). However, no avoidance or reduced feed intake of the pea-based diet was observed during the training period, which supports the results obtained in the preference test. The intake of pea and canola diets during the training period was similar to the expected feed intake (Prairie Swine Centre Inc. 2000). These results clearly indicate that peas do not cause negative post-ingestive effects.

During both the training period and the preference test, the animals were given access to feed for only four hours per day. However, limited time feeding did not affect the feed intake of

pigs as the intakes recorded were similar to the expected feed intake. Since the animals had limited access to food there is reason to suspect that they might choose to eat pea-containing diets even though these might contain anti-nutritive factors. A study with sheep showed that this is not true. Food deprived sheep ate lesser amounts of barley with toxins than animals that were fed ad libitum (Wang and Provenza, 1996). Furthermore, in our study during the preference test the animals were given a choice between two flavoured diets corresponding to pea and canola diets and they should have preferred the flavoured diet corresponding to canola if the pea diet caused digestive discomfort.

These results indicate that the preference of pea and canola-based diets used in this study were similar, suggesting that the effect of pea inclusion on feed intake was not affected by post-ingestive feedback.

5 FEEDING BEHAVIOUR OF GROWER PIGS DURING A TRANSITION TO PEA-BASED DIETS

5.1 Introduction

Feeding behaviour is an important factor that has to be considered in animal production because it is how an animal achieves feed intake, which is necessary for growth (Emmans and Kyriazakis, 2001). In addition to controlling intake, monitoring feeding behaviour aids in various other management issues such as disease assessment (Urton, 2005). Environment, health, and social interactions are some factors that affect feeding behaviour (Grant and Albright, 1995).

Animals are usually neophobic in nature meaning they try to avoid eating novel feed or eat them initially in small quantities (Visalberghi and Fragaszy, 1995). If an animal gets sick after eating a familiar (previously exposed) and novel meal the animal will avoid the novel food (Revusky and Bedarf, 1967) and if the animal consumes a series of only novel foods then the animal would avoid the most novel food (in order of consumption) (Provenza et al., 1994b). Based on the above two concepts an animal can reject a novel food based on avoidance (neophobia) or learned aversion. This might create complications in commercial production systems as animals are usually presented with different kinds of diets during different growth stages. Monitoring their behaviour during periods of transition might give insights into their preference for the feed.

Peas are high in digestible energy and lysine (Davis et al., 2002) and constitute an excellent feed ingredient for swine. However, despite this, their reputation as an ingredient with bad taste limits their use. A survey was conducted by Pulse Canada in 2007 among Canadian feed producers. The three major factors that were mentioned to explain why they limited the inclusion of peas in swine rations were: 1) palatability, 2) nutritional variability and 3) diet transition. For example, the maximum recommended inclusion rate of peas in diets for grower-finisher pigs was 22 % in Western Canada whereas it has been shown that an inclusion rate of 66 % can be accomplished without any negative effects on performance (Stein et al., 2006).

One of the most popular models of food selection is hedyphagia where the animals select foods based on their oro-sensory reward. The reason put forth by advocates of this model is that animals have an innate ability (as a result of evolution) to avoid tastes such as sour and bitter, as

it warns them of toxins or spoilage (Provenza, 1995b; Bernstein, 1998). There are very few studies that have discussed the effect of peas on the feeding behaviour of pigs. To our knowledge, only one experiment has been recently carried out. In that study Mathe et al. (2003) evaluated the effects of peas on the behaviour of pigs when the latter were given a pea-based diet. Four different inclusion rates of peas were used (0, 13, 26 and 39). The authors studied the behaviour of pigs during the transition to pea diets and concluded that the presence of peas modifies feeding behaviour (increased time spent on food and reduced rate of ingestion), but further studies were recommended.

The objective of this study was to study the short term feeding behavior of pigs when presented with a novel pea diet.

5.2   Materials and methods

5.2.1   Facilities and animals

The experiment was conducted in the intensive room at the Prairie Swine Centre. This room consists of 76 pens, 0.91 x 1.83 m (1.67 m^2) pens housing pigs individually, allowing control of individual feed intake. Pens have pre-cast concrete slatted floors and solid PVC planked sides. The pens had a 7.5 cm wide opening on the back wall to allow social contact. Unlimited water supply was provided through nipple drinkers positioned at the centre of the rear wall. Single space dry feeders were placed in the front of each pen during feeding time.

A total of 30 grower barrows weighing an average of 33 ± 4.5 kg were used in the study. The pigs were housed individually to measure individual feed intake and behaviour. The pigs were given a period of 7 days for acclimatization to the new environment, during which they were provided with the basal diet.

The University Committee of Animal Care at the University of Saskatchewan reviewed and approved the animal care protocol for the experiment (protocol # 19970019).

5.3 Experimental design

5.3.1 Determination of meal criteria

Several methods based on the frequency distribution of intervals betweeen bouts of eating are used to determine meal criteria. These include usage of log survivorship function to establish a criterion for the shortest intermeal interval (Bigelow and Houpt, 1988), selecting the interval with the lowest frequency (de Castro, 1981). In the present study meal criteria interval was determined by examining the frequency histogram of intervals between meals and the log survivorship curve (Machlis, 1977; Slater, 1974). When a behaviour occurs in intervals the slope of the curve is steep initially and then becomes gradual as the interval gets longer. The steep section is the within-meal intervals and the gradual section is the between meal intervals. The break point between these two portions when visually observed gives the meal criteria interval (Figure 5.1).

5.3.2 Treatments

Five dietary treatments were used. Two samples (Sample A and Sample B) of field peas were obtained from different farms in the same area of Western Saskatchewan and incorporated at 40 % as coarse ground (800 µm) or fine ground (600 µm), in a 2 x 2 factorial arrangement of diets (Table 5.1). This study was part of another study which looked at the effect of grind sizes on digestibility and hence the usage of two different grinds. A control (familiar) diet (SBM-based) with a grind size of 800 µm was used as reference. All the diets were fed in the mash form.

The feed was supplied ad libitum. The study had a test period of 7 days where behaviour of the animals was recorded on day 1, day 4 and day 7. Several video cameras were used to record the behaviour of pigs for a period of 12 hours, beginning at 8 am. Feed intake was measured every 3 days.

The beginning and end of each eating occurence was recorded on a continuous basis. The recordings were viewed back by one observer at normal speed. Inter-event intervals were analysed to determine the appropriate inter-bout (meal) interval. The variables measured include a) total eating time - total amount of time with head in feeder, b) number of meals - number of

meals based on bout criteria c) total meal time - time during meals including within-bout intervals, d) average meal time – total meal time/number of meals, e) average eating time – total eating time/number of meals and f) intensity – total eating time/total meal time * 100.

The experiment used a completely randomized block design. Different time periods were considered as blocks. There were 3 blocks with 10 pigs used in each block. The pigs within a block were randomly assigned to one of the five diets (6 pigs/treatment x 5 treatments = 30 pigs). The data were analysed using two separate analysis. The first analysis was done to allow a comparison of the reference SBM diet with the pea based diets. The data were analysed as a completely randomized design with day as a repeated measure. Behavioural measures were used as the variable and block was considered a random effect. The interaction of treatment and day was also analysed. The data were analysed using the Proc mixed procedure of SAS (Version 9.2) where the individual pig was the experimental unit and the statistical model examined the fixed effects of treatment.

In the second analysis the data were analyzed using a 2 x 2 factorial arrangements of treatments to compare the main effects of source and grind, with day being a repeated measure. The SBM diet was excluded from this comparison. Behavioural measures were used as the variable and block was considered a random effect. The interactions of source, grind and day were also analysed. The data were analysed using the Proc mixed procedure of SAS (SAS/STAT Version 9.2, SAS Institute Inc., Cary, NC, USA) where the individual pig was the experimental unit and where the statistical model examined the fixed effects of treatment.

A partial correlation analysis, based on residuals after treatment effects were accounted for, was also done using the Proc GLM procedure of SAS (SAS/STAT Version 9.2, SAS Institute Inc., Cary, NC, USA). The variables analysed include total eating time, number of meals, total meal time, average meal time, average eating time and intensity. In all instances, significance was declared when $\alpha = 0.05$.

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Table 5.1: Formulation of pea diets. Peas were from one of two samples and diets fed as either coarse or fine ground (800 µm or 600 µm)

Ingredients (% as fed)	Amount (%)
Wheat	47.71
Soybean meal	9.00
Peas	40.00
Monocalcium phosphate (21 % P)	0.90
DL - Methionine	0.04
Limestone	1.20
Salt	0.35
Mineral mix	0.10
Vitamin mix	0.10
[z]Celite	0.60

[z]used as an inert digestibility marker

5.4   Results

All the animals used were healthy and none had to be removed from the study. Figure 5.1 shows the slope of the curve when a frequency histogram was plotted using the data obtained from the study. The steep section is the within-meal interval and the gradual section is the between meal interval. The intersection of both these sections depicted by the lines in the figure gives the meal criteria interval (Slater, 1978). The meal criteria interval chosen by visual inspection of feeding was 7 minutes. Intervals between eating events greater than 7 minutes were used to define meals.

An effect of day was observed for three behavioural measures - number of meals, average meal time and average eating time per meal ($P < 0.01$) (Table 5.2) . The number of meals reduced from 13.3 on day 1 to 10.6 on day 7. The average meal time increased from 10.9 to 14.7 minutes per meal while the average eating time increased from 8.9 to 12.2 minutes per meal over the test period.

A treatment by day interaction was observed for total eating time ($P = 0.02$). The total eating time for pigs on sample A fine diets decreased from 114 minutes to 94 minutes from day 1 to day 7. The pigs on sample B coarse diets spent more time eating on day 4 (130 minutes) than day 1 (107 minutes).

Comparing the familiar (SBM) diet with the remaining diets, it was observed that pigs on the familiar diet had fewer meals ($P = 0.03$), but that these meals were longer in terms of average meal time ($P = 0.04$). The average meal time of pigs fed pea diets were 12.2 minutes while the average meal time for pigs on the control diet was 14.7 minutes. Pigs on the control diet consumed 9.3 meals per day as opposed to 12.6 meals consumed by the pigs on pea diets. There was a tendency for the average eating time to be higher for pigs on control diet (12.4 minutes) than the pigs on pea diets (10.2 minutes) ($P = 0.08$).
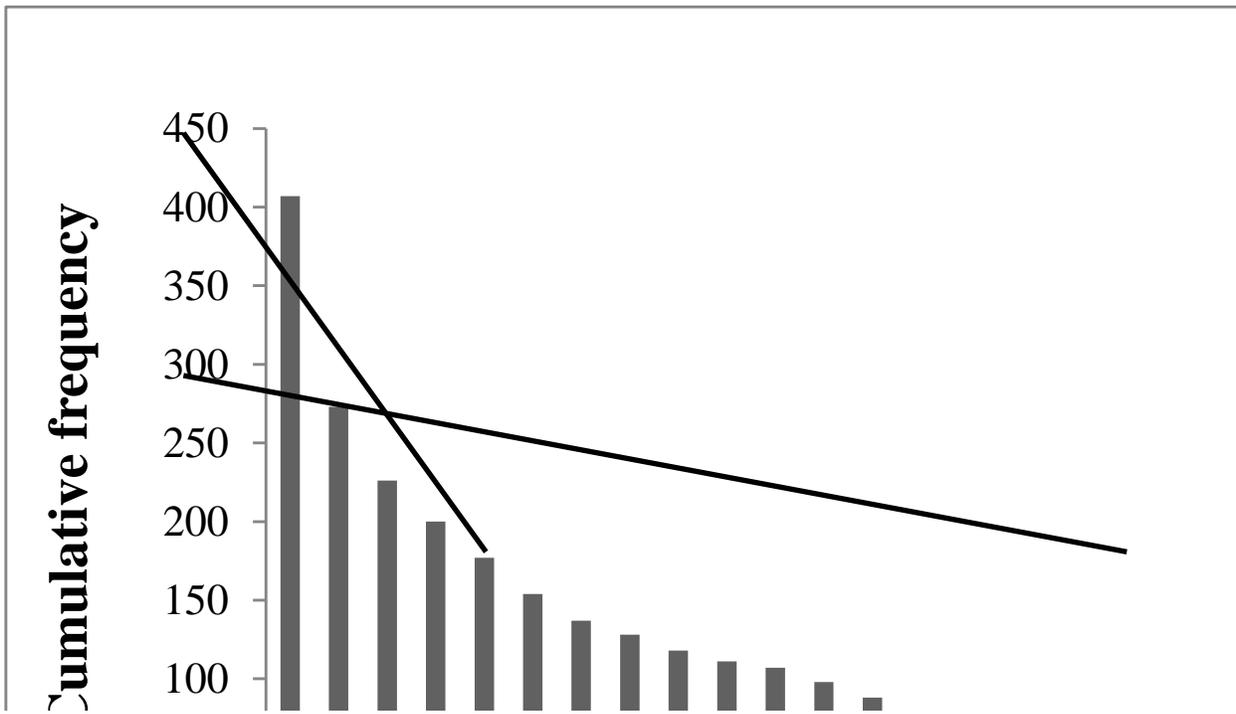
Figure 5.1: Frequency histogram of intervals between consecutive feedings used to determine the meal criteria interval.

Table 5.2a: Eating behaviour over a 12-hr period of pigs fed a familiar soybean meal based diet or one of four pea based diets differing in sample and grind[z]

	Peas						P values			
	Sample A		Sample B							
							SBM vs	Overall		Overall
	SBM	Coarse	Fine	Coarse	Fine	SEM	Peas	Trt	Day	Trt*day
TET(sec)[y]	106.8	112.2	104.1	120.6	131.2	9.15	0.32	0.24	0.37	0.02
NOM[x]	9.3	11.6	13.6	11.0	14.0	1.25	0.03	0.07	<0.01	0.69
TMT(sec)[w]	128.0	136.4	134.9	140.3	163.0	11.67	0.24	0.29	0.85	0.10
AMT(sec)[v]	14.7	12.7	10.3	13.8	12.0	1.0	0.04	0.06	<0.01	0.12
AET(sec)[u]	12.4	10.6	8.3	12.1	9.7	1.1	0.08	0.08	<0.01	0.32
INT(%)[t]	84.7	83.8	78.3	88.9	80.5	4.07	0.69	0.42	0.22	0.94

[z]Data analyzed as a randomized block design with 5 treatments

[y]TET - total eating time (total amount of time with head in feeder)

[x]NOM - number of meals (number of meals based on bout criteria interval of 7 min)

[w]TMT - total meal time (time during meals, including within-bout intervals)

[v]AMT - average meal time (TMT/NOM)

[u]AET - average eating time per meal (TET/NOM)

[t]INT - intensity (TET/TMT)*100

The results utilizing a 2 x 2 factorial arrangement of treatments examining pea sample and grind is presented in Table 5.3. An effect of day alone were observed for number of meals, average meal time and average eating time per meal (P < 0.01). The number of meals reduced significantly from day 1 (14.1) to day 4 (12.5) and to day 7 (11.08). There was significant increase in the average meal time spent by animals on day 7 (14 minutes) compared to day 4 and day 1 respectively (12 and 10.7 minutes). There was a significant increase in average eating time per meal from day 1 (8.6 monutes) to day 4 (10.3 minutes) and to day 7 (11.7 minutes) over the test period.

There was a tendency for a significant difference in total eating time between sample A (108 minutes) and sample B (126 minutes) (P = 0.07). When grind alone was considered there was a tendency for significant differences in number of meals (13.8 for fine diets versus 11.3 for coarse diets) and average meal time (13.3 minutes/meal for coarse diets versus 11.2 minutes/meal for fine diets) (P = 0.07). Pigs on finely ground diets (13.8) consumed more meals than the ones on coarse diets (11.3).

Several significant grind by day effects were observed for total eating time, total meal time, average eating time and average meal time (P < 0.01). There was a significant increase in the total eating time of coarse diets from day 1 to day 4 (Figure 5.2a). When the total meal time was considered there was a difference between the coarse and fine diets on day 1 (Figure 5.2b). There was also an increase in total meal time from day 1 to day 4 for coarse diets (Figure 5.2b). The average eating time and average meal time increased over time for the coarse diets (Figure 5.4 and Figure 5.5).

Table 5.2b: P values for eating behaviour over a 12-hr period of pigs fed four pea based diets differing in sample and grind[z]

	Sample	Grind	Day	Sample* Grind	Sample* day	Grind*Day	S*G*D
TET(sec)[y]	0.07	0.89	0.28	0.36	0.21	0.02	0.57
NOM[x]	0.95	0.07	<0.01	0.70	0.77	0.18	0.86
TMT(sec)[w]	0.19	0.40	0.92	0.35	0.22	0.04	0.82
AMT(sec)[v]	0.24	0.07	<0.01	0.78	0.60	<0.01	0.64
AET(sec)[u]	0.23	0.06	<0.01	0.98	0.82	<0.01	0.66
INT(%)[t]	0.37	0.10	0.28	0.70	0.48	0.75	0.99

[z]Data (LSmeans shown in table 2) analyzed as a 2 by 2 factorial comparing the effects of sample, grind, day and all interactions

[y]TET   -   total eating time (total amount of time with head in feeder)

[x]NOM   -   number of meals (number of meals based on bout criteria interval of 7 min)

[w]TMT   -   total meal time (time during meals, including within-bout intervals)

[v]AMT   -   average meal time (TMT/NOM)

[u]AET   -   average eating time per meal (TET/NOM)

[t]INT   -   intensity (TET/TMT)*100
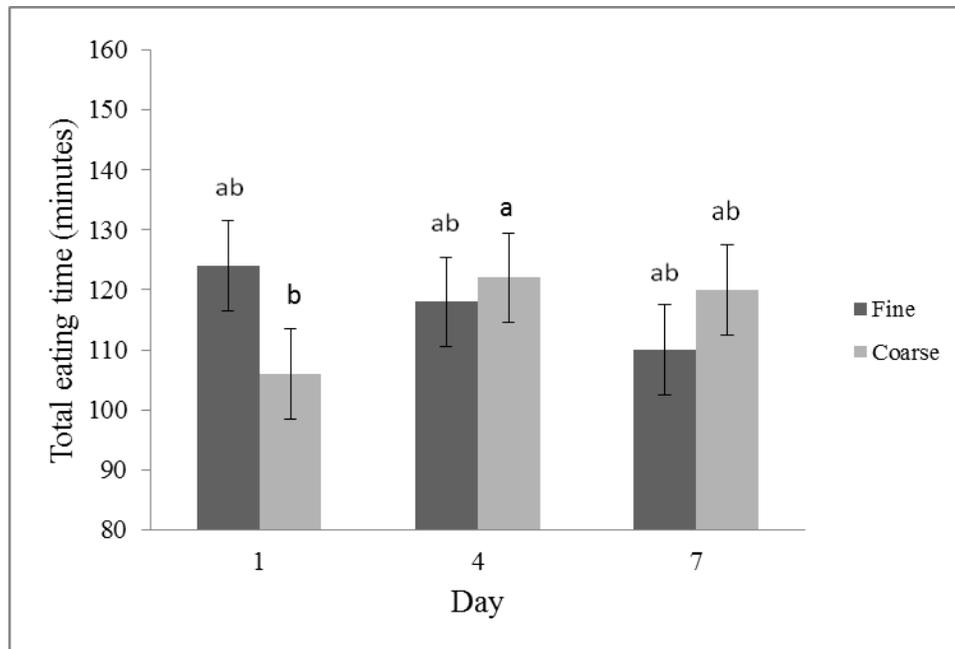
Figure 5.2: The effect of grind and day on total eating time (minutes) of pigs fed four pea based diets differing in sample and grind over a period of 12-hours. Means with the same letters across and within days are not significantly different (P = 0.02; SE = 7.49).
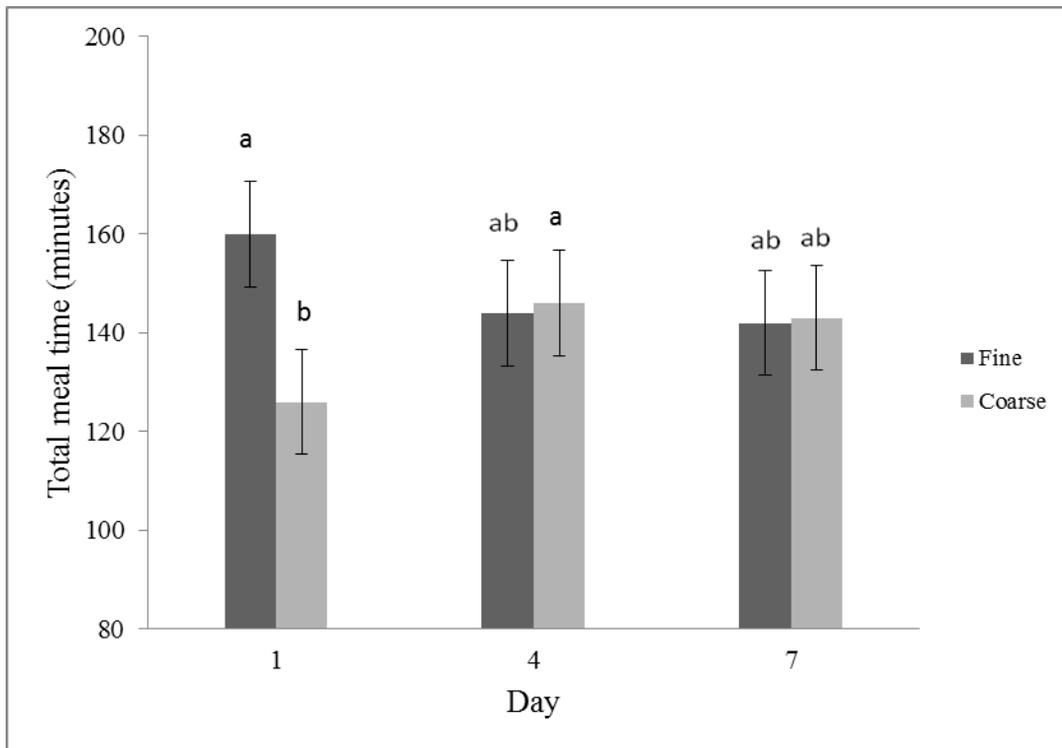
Figure 5.3: The effect of grind and day on total meal time (minutes) of pigs fed four pea based diets differing in sample and grind over a period of 12-hours. Means with the same letters across and within days are not significantly different ($P = 0.04$; SE = 10.63).
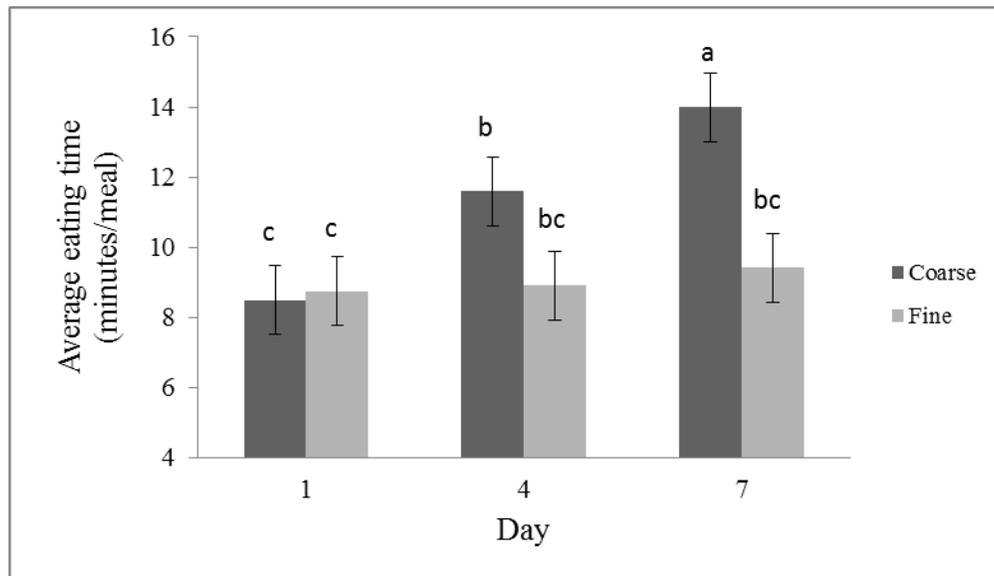
Figure 5.4: The effect of grind and day on average eating time (minutes/meal) of pigs fed four pea based diets differing in sample and grinds over a period of 12-hours. Means with the same letters across and within days are not significantly different ($P < 0.01$; SE = 0.98).
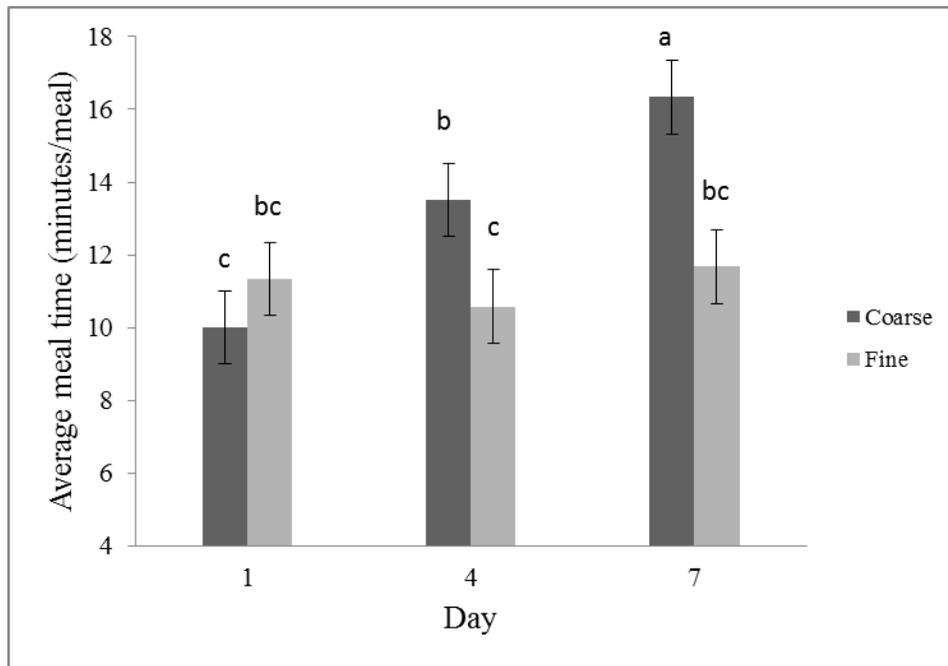
Figure 5.5: The effect of grind and day on average meal time (minutes/meal) of pigs fed four pea based diets differing in sample and grinds over a period of 12-hours. Means with the same letters across and within days are not significantly different ($P < 0.01$; SE = 1.01).

No difference in feed intake between the pea and soybean meal diet ($P > 0.05$) was seen during the test period but there was a day effect as the consumption increased over time for all the diets ($P < 0.05$). The partial correlation analysis (Table 5.8) with the exceptions of intensity and total eating time, intensity and average meal time and average eating time and total meal time showed that the behavioural measures were significantly correlated with each other. The total eating time was positively correlated to the number of meals, total meal time, average eating time and average meal time. The number of meals was positively correlated to total meal time but negatively correlated to average eating time, average meal time and intensity. The total meal time was positively correlated to average meal time but negatively correlated to intensity. The average eating time was positively correlated to average meal time and intensity.

Table 5.3: The partial correlation coefficient[z] and significance[y] values of the partial correlation analysis for the behavioural measures of pigs fed a familiar soybean meal based diet or one of four pea based diets differing in source and grind

	TET	NOM	TMT	AET	AMT	INT
TET[x]	1.00	0.26	0.80	0.41	0.50	0.01
		0.05	**<0.01**	**<0.01**	**<0.01**	**0.92**
NOM[v]		1.00	0.51	-0.69	-0.55	-0.51
			<0.01	**<0.01**	**<0.01**	**<0.01**
TMT[u]			1.00	0.04	0.36	-0.58
				0.77	**<0.01**	**<0.01**
AET[t]				1.00	0.90	0.50
					<0.01	**<0.01**
AMT[s]					1.00	0.09
						0.47
INT[r]						1.00

[z]standard font – r values

[y]bold font – P values

[x]TET   -   total eating time (total amount of time with head in feeder)

[v]NOM   -   number of meals (number of meals based on bout criteria interval of 7 min)

[u]TMT   -   total meal time (time during meals, including within-bout intervals)

[t]AMT   -   average meal time (TMT/NOM)

[s]AET   -   average eating time per meal (TET/NOM)

[r]INT   -   intensity (TET/TMT)*100

5.5   Discussion

Food neophobia is a phenomenon whereby because of unfamiliarity and as a protective mechanism to avoid potentially harmful food before ingesting them, animals sample novel foods (Chapple and Lynch, 1986; Wong and McBride, 1993). Studies by Nicol and Pope (1994) show that young pigs display neophobic responses to novel diets; however, the response is reduced by pre-exposure to the sight and smell of the diet.

Animals reared in production systems receive different diets during their life. The composition of food changed to meet the animal's requirements and due to the cost of ingredients (Kyriazakis et al., 1990). The transition to new diets may result in behavioural changes because of factors like neophobia (Visalberghi and Fragaszy, 1995), and change in food type (physical characteristics) (Whittemore et al., 2002). The current study was designed to monitor the short term feeding behaviour of pigs when presented with novel pea diets.

The behaviour of pigs was recorded only during the light period of 12 hours during the study. Previous work on feeding behaviour in pigs' show that the majority of the feeding in pigs occurs during the light period suggesting a strong diurnal pattern of food intake (Bigelow and Houpt, 1988; Montgomery et al., 1978). The number of meals and percent of daily food intake was high during the light period (Bigelow and Houpt, 1988).

In the first analysis, when the behavioural measures for SBM were compared to that of peas, the pigs on pea diets ate more meals but the average meal time and average eating time of meals were shorter. The animals on the pea diets consumed more meals but spent less time eating (total and average eating time). This response can be indicative of neophobia. A study by Mathe et al. (2003) showed that a transition to pea diets caused behavioural changes but did not cause detrimental consequences to pig growth. The results obtained from Mathe's study showed that the presence of peas in the diet increased the time spent feeding by pigs but decreased the rate of ingestion during the transition. There was no difference in feed intake in this study as opposed to reduced feed intake reported by Mathe et al. (2003) during the transition period. Feed intake during transition to new diets is affected by competition for access to food and other environmental factors (Mathe et al., 2003). Group housed pigs have a significantly lower growth rate than individually housed pigs (de Haer and de Vries, 1993). Since the animals used in this experiment were individually housed there was no competition for access to food. This might

explain why a reduction in feed intake was not observed as housing systems significantly affect the feed intake pattern.

Daily food intake is the sum of individual meals. Meal size is determined by negative feedback controls that are initiated when the nutritional deficit incurred during the intermeal interval is met (Houpt, 1984). A meal is initiated when blood glucose declines (nutritional deficit) below a base level (Campfield et al., 1985) and is terminated when the deficit is met (Houpt, 1984). The meal criteria interval determined and used in this study was 7 minutes which was similar to the one used by Petrie and Gonyou (1988). Studies by Kisseleff (1970) with rats show that in a free feeding system (ad-libitum feeding) altering the intervals did not vary the frequency distribution of meal sizes greatly and suggests 10 to 20 minutes as the dividing point.

The mean number of meals consumed per day by pigs weighing 23 to 39 kgs was reported to be 9 to 10 by Montgomery et al. (1978). The number of meals for pigs used in this study varied from 9 to 14, depending on treatment. The average number of meals consumed by pigs on the SBM diet, which was the familiar control, was 9 and is similar to the results observed by Montgomery et al. (1978). Studies by Bigelow and Houpt (1988) using pelleted feed showed the number of meals for pigs weighing 30 to 40 kgs to be 10. A classic theory by Montgomery (1955) describes that a novel stimuli produces two different kinds of responses – curiosity (promotes investigatory response) and fear (inhibits investigatory response). Exploratory behavior is the outcome of both these competing tendencies to avoid or approach. An animal's natural initial response to novelty is neophobia followed by exploratory behavior and then neo-philia if there are no negative effects (Misslin and Cigrang, 1986). Based on this an animal's response to a novel feed is exploratory in the beginning and turns neophilic if there are no negative consequences. The number of meals reduced over time for animals on pea diets (Figure 5.2). However, the average meal time and average eating time increased over the test period for the animals on pea diets. As the animal got used to the novel feed by experiencing no post-ingestive consequences the exploratory behaviour was reduced and the feeding behaviour became similar to the animals being fed the SBM (familiar) diet.

The second statistical analysis examined the main effects of source and grind. The SBM diet was excluded from the analysis and day was included as a repeated measure. There was no source effect showing that peas used in the study did not differ in terms of acceptance by the pigs. However there was evidence of a day effect which was seen in the first analysis as well.

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The longer the animal was exposed to the food its initial neophobic response reduced and therefore the number of meals decreased and the AMT and AET increased over time.

The analysis also revealed a grind by day effect. Animals on the coarsely ground pea diets spent less time eating on day 1 but by day 4 the TET of coarsely ground pea diets was not different from the other diets. A study by Yo et al. (1997) showed that varying particle size of feeds affected feeding behaviour. Birds receiving larger particles (whole corn) spent half the time eating compared to birds fed ground corn. These results are similar to the current study suggesting that feeding large particles might reduce eating time. However, the effect in pigs seemed to be transient as the total eating time of pigs being fed coarse diets was similar to the other diets by the end of the test period.

Decreasing the particle size of feed ingredients reduced feed intake in finishing pigs (Wondra et al., 1995) and piglets (Healy et al., 1994) and possible reasons for this are increased digestibility of amino acids with smaller particle size (Fastinger and Mahan, 2003). In this study a difference in feed intake was not seen. These results support the results presented by Sola-Oriol et al. (2009) where particle size did not seem to affect feed preference in pigs.

The partial correlation analysis revealed the relationship between the various behavioural measures. An increase in number of meals, total meal time, average eating time and average meal time increased the total eating time, which is expected. Negative relationships were observed between number of meals and average eating time, average meal time and intensity. This result indicates that an increase in eating time per meal reduces the number of meals. However an increase in average meal time and average eating time increase the total meal time.

In general, pigs fed the pea (unfamiliar) diets had more and shorter meals early in the study indicating a transition to the new diets. When the soybean meal and coarse pea diets were compared there was a significant difference in the number of meals and amount of time spent eating by pigs on the first day. However, the number of meals and time spent eating did not differ at the end of the trial period. Pigs eating the finely ground diets continued with more meals throughout the study, indicating that either the transition was not complete or that the fine grind required fewer meals in general.

6   GENERAL DISCUSSION AND CONCLUSION

Canadian feed producers incorporate a maximum of 19% of peas in rations for growing pigs (Pulse Canada, 2007). Based on nutrient composition, this inclusion rate could be higher. Typically, feed producers incorporate less of any specific ingredient than what is theoretically possible to have a security margin. Anecdotally speaking, if a maximum of 30 % is recommended, they will include a maximum of 20 %. The inclusion rates are not sustained by scientific information. According to French studies, peas can represent more than 40 % of balanced diets for weaned and growing pigs, without any adverse effect on feed intake or growth (Gatel et al., 1991; Grosjean et al., 1997). Moreover Stein et al. (2006) showed that inclusion rates of 60 % did not affect the palatability of pork.

One reason peas are underused is due to their supposed bitter taste (Pulse Canada, 2007) and also because they are incorporated into balanced diets with other feed ingredients that might also have a bad or bitter taste. For example, canola meal (CM) is a feed ingredient widely produced and used in Western Canada. The bitter taste of CM comes from the presence of phenolic compounds (Naczk et al., 1998). Peas are often used together with CM because both ingredients are produced in western Canada and have proteins with complimentary amino acid profiles. The high methionine content of CM proteins compensates for the deficiency in pea proteins, whereas peas provide important amounts of lysine (Aherne and Bell 1990; Castell 1990). Despite producers' concerns regarding the issue of pea taste, it hasn't been addressed in previous studies.

The series of experiments conducted in this study demonstrate that peas are palatable to swine. The first experiment revealed that there was no difference in intake over relatively short transition periods (transition from familiar to novel pea diets). An inclusion rate of up to 60 % did not reduce intake in grower pigs. No evidence of an innate taste aversion was seen. A taste issue would have immediately reduced the intake of the pea diets. However, a drop in intake was not noticed during the transition period. Results from the second experiment support the results of the first experiment that peas did not cause a negative post-ingestive effect. This is evidenced by the fact that the animals chose to eat equal amounts of the flavor associated with pea and canola diets. Kyriazakis and Emmans (1992) studied the diet selection of pigs when fed diets containing rapeseed meal which produces goitrogenic effects. The inclusion did not affect the

intake and live weight gain of pigs fed rapeseed meal alone. This finding is similar to the result from the first experiment of the present study. However, in Kyriazakis's study when the pigs were given a choice between a rapeseed meal and soybean meal diet the pigs chose the soybean meal diet irrespective of the nutritional properties of the diets. This clearly indicates that the pigs preferred the soybean meal diet over the rapeseed meal diet because of negative effects of the rapeseed meal. This was not the case in the second experiment confirming the fact that commercially available peas used in this study did not cause negative effects because of either taste or post-ingestive feedback issues.

The third experiment gives insight into the feeding behavior of pigs during transition to a pea based diet. The pea diets modified the feeding behavior of pigs during the transiton period. The pea diets required a larger number of meals and the meals were shorter in length during the initial phase of the adaptation period. However, the feeding behavior became similar to the feeding behavior of pigs on the soybean meal (familiar) diet within a week. This feeding pattern is suggestive of neophobia that corrects within a few days of exposure. The initial response of more feeder visits and reduced time spent eating per visit results in a reduced ingestion per meal, thereby reducing ingestion of toxic substances. Time required for grower pigs to adapt to a novel constraining diet varies from 7 to 14 days depending on previous exposure (Kyriazakis and Emmans, 1995; Whittemore et al., 2001). The pigs in this experiment adapted to the diet within 7 days.

There is evidence that animals can regulate consumption of a harmful food over time so that the toxic threshold is not surpassed. High consumption of intake for a day or two is followed by a period of low consumption. This gives the animal enough time to detoxify itself (Pfister et al., 1997). Such a feeding pattern was not observed in the present study suggesting that peas do not cause any harmful effects.

This series of studies was conducted to provide a better understanding of the response of pigs to the inclusion of Canadian peas in the diet because of the concern of producers regarding palatability. The results revealed that peas did not have negative effects on intake. Possible reasons for producers observing reduced feed intake might be because of usage of nutritionally unbalanced diets or because of the usage of particular varieties of peas that have a higher concentration of anti nutritive factors. The recommendations and practice of using low levels of peas in diets may have developed prior to routine supplementation with tryptophan a limiting

amino acid in peas. A tryptophan deficiency could cause reduced feed intake (Eder et al., 2001). Moreover, the reluctance of producers to use peas might not have stemmed from personal experience but through second hand knowledge or misinformation. The fact that there might be differences between different strains of animals with regard to neo-phobia and taste aversion learning (Cannon and Carrell, 1987) also has to be taken into consideration.

In conclusion, the series of experiments help to clarify whether pea taste is a problem or not. The flavour of a food is an important component that contributes to it being widely consumed. Annual production of field peas range from 3.0 to 3.7 million tonnes and constitute a major source of income for farmers in western Canada. Canada is the main producer of peas in the world. There is a potential to use more Canadian peas in animal nutrition and pea proteins in the feed industry.

Feed producers use more imported soybean meal than locally grown field peas, despite the difference in prices. A consequence of this study might encourage producers to incorporate higher rates of field peas thus lowering production costs. The same can be said for the main importers of Canadian peas, pet food industry and food ingredient industry where pea proteins are slowly replacing soy proteins in many foods produced.

7 LITERATURE CITED

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APPENDIX

This appendix is designed to present the data for the preliminary experiment which was conducted to choose the flavours to be used in the main study "Use of flavour association and preference tests to assess the palatability of pea diets". The objective of the experiment was to choose two different flavours which had the least preferential difference to remove flavour effect in the main study.

A.1   Preliminary experiment to select two flavours with minimal differences in innate preference

A.1.1   Materials and methods

A.1.1.1   Rooms

The experiment was conducted in the intensive room at the Prairie Swine Centre. This room consists of 76 pens, 0.91 x 1.83 m (1.67 m^2), and housing pigs individually. The pens consisted of pre-cast concrete slatted floors and solid PVC planked sides. To prevent isolation stress the pens had a 7.5 cm wide opening on the back wall to allow social contact. Unlimited water supply was provided through nipple drinkers positioned at the centre of the rear wall. Single space dry feeders were placed in the front of each pen.

A.1.1.2   Animal selection, identification and care

Animals used in the experiment weighed 20.5 ± 1.3 (mean ± SD) kgs. Twenty four pigs of mixed gender were used. The feed treatments were not anticipated to cause pain or distress. This research protocol was approved by the University of Saskatchewan's Animal Care Committee, which is regulated by the Canadian Council on Animal Care.

A.1.1.3   Diets

A basal familiar soybean meal diet (SBM) was used in the study. The diet was formulated to meet or exceed the nutrient requirements of the grower pig (NRC, 1998). The diet was prepared at Masterfeeds Inc., Saskatoon. Diets were fed for an 8 hour period. Ingredient composition of the diet is shown in table A.1.

Table A.1: Ingredient composition of the diet (% as fed) used in the study

Ingredients	SBM
Wheat	51.45
Soymeal	30.60
Oatgroats	10.00
Fish meal	4.50
Mono/dical	1.00
Tallow	1.00
Limestone	0.50
Salt	0.20
[z]Masterfeeds Inc. Mineral mix	0.20
[z]Masterfeeds Inc. Vitamin mix	0.10
DL-methionine	0.02
L-threonine	0.08
L-typtophan	-
Choline chloride	0.07
ZnO Zn72 %	0.03
Lysine HCl	0.26

[z]Masterfeeds Inc. - 330, 103rd Street East, Saskatoon, SK, S7N 1Z1

A.1.1.4   Treatments and data collection

Four different flavours were used in the experiment. The experimental period was one day and the pigs were fed ad libitum for 8 hours. The SBM diet was flavoured by the addition of 6 g/kg of one of four Kool-Aid[TM] flavours immediately prior to feeding. The Kool-Aid [TM] flavours that were used included orange, grape, cherry and strawberry. Six pigs were assigned to each flavour. The feed intake was measured at the end of 8 hours.

A.1.2 Results and conclusion

Table A.2: The mean feed intake data of the pigs used in the study

Flavour	Mean feed intake (kgs)
Orange	1.10
Grape	1.10
Strawberry	1.18
Cherry	1.22

According to the results cherry flavour had the highest intake whereas orange and grape flavours had similar intakes. Based on the mean feed intake orange and grape flavours were chosen as they had the least preferential difference. The objective of this experiment was to choose flavours that would affect intake similarly, to remove the flavour effect from the main study.