NUTRITIONAL EVALUATION OF INDUSTRIAL FOOD WASTES IN DUCKS DIETS

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A Thesis

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ABSTRACT

Nutritional Evaluation of Industrial Food Wastes in Duck Diets

Six hundred day-old Pekin and Muscovy male ducklings were raised on diets based exclusively on food wastes to market ages of 7 and 11 weeks, respectively. Three dietary treatments were offered to the birds: commercial pellets (control), feeds consisting partially of food waste, and feeds consisting entirely of food waste. The two experimental treatments each had a dry pelleted diet and a wet mash diet. Body weight was not significantly different ($P > 0.05$) for the Pekin and Muscovy ducklings fed the diet containing partial food waste and the diet containing 100 % food waste when compared to the control diet . Both Pekin and Muscovy birds consumed less feed of the diets containing food waste than those on the control. Feed efficiency was significantly better ($P < 0.05$) for the Pekin breed and for the experimental dietary treatments for both breeds. However, the birds fed food waste diets consumed significantly higher proportions of fat and less protein due to the characterized chemical composition of the waste ingredients used in the ration formulations. Twenty-four carcasses from each breed were analyzed to determine the effects of the experimental diets compared to those of the control (commercial pellets). The Pekins had significantly ($P < 0.05$) higher skin and fat % than the Muscovies, while the latter breed had a significantly higher ($P < 0.05$) meat and bone %. Within the Pekin breed, ducklings fed food waste diets had significantly ($P < 0.05$) higher skin and fat % than the ducklings fed the commercial control diet. Fatty acid analysis of the subcutaneous fat of both breeds showed significant ($P < 0.01$)

differences in profiles. Most remarkable was the higher monounsaturated fatty acid proportions in the Pekin profile compared to that of the Muscovy (51.79 vs 9.61 %) which contained a significantly ($P < 0.01$) higher percentage of polyunsaturated fatty acids (35.60 vs 17.41 %). In addition to corn and soybean meal, a total of nine food waste ingredients were tested. The precise-feeding technique was performed to establish DM, fat, and fibre digestibility as well as N retention, AME, AMEn, TME, TMEn values for the 11 feedstuff ingredients. Peanut had significantly ($P < 0.05$) the highest energy value followed by pogo, granola, tofu, the food waste diet, bread, corn, soybean meal, brewers grain, okara, and peanut skins with 5195, 4195, 4019, 3967, 3498, 3220, 3216, 2357, 1829, 1712, and 1244 kcal AMEn/kg, respectively. Bread NDF was significantly ($P < 0.05$) the most digestible (88.9 % NDF digestibility) as it contained 96.29 % hemicellulose while okara NDF, besides peanut skins and soybean meal, was significantly ($P < 0.05$) the least digestible (26.94 % NDF digestibility) as it contained 14.38 % hemicellulose. The results of this study provide reliable data for formulation of duck diets using the tested food waste ingredients as well as corn and soybean meal in both Pekin and Muscovy ducklings at 2 different ages during growth.

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SOMMAIRE

Evaluation Nutritionnelle des Déchets de l'Industrie Agro-Alimentaire par des Rations pour les Canards à Chair

Six cent canetons mâles (Pékin et Barbarie) âgés d'un jour ont été élevés à partir de diètes basées exclusivement de déchets alimentaires jusqu'au poids du marché. Pour les Pékins, ceci représente 7 semaines et 11 semaines pour les Barbaries. Les trois diètes expérimentales offertes aux oiseaux étaient:diète commerciale texturisée (contrôle), ration consistant en partie de déchets alimentaires et ration consistant en totalité de déchets alimentaires. Chacun des deux traitements expérimentaux étaient offert sous 2 formes: moulée texturisée et moulée humide. Le poids ne montrait pas de difference significative ($P > 0.05$) pour les canetons Pékins et Barbaries nourris avec la diète consistant en partie, ou en totalité, de déchets alimentaires, comparativement avec le contrôle. Les Pékins et les Barbaries ont tous deux consommé moins des rations contenant des déchets alimentaires que de la diète commerciale contrôle. L'efficacité alimentaire était significativement meilleure ($P < 0.05$) pour la race Pékin, ainsi que pour les traitements alimentaires expérimentaux pour les 2 races. Cependant, les oiseaux nourris de déchets alimentaires ont consommé des proportions plus élevées de gras et moins élevées de protéines dû à la composition chimique des déchets alimentaires utilizés. Vingt-quatre carcasses représentant les 2 races ont été analysées pour déterminer les effects des diètes expérimentales comparés à ceux de la ration témoin (moulée commerciale texturisée). Les Pékins avaient significativement ($P < 0.05$) un plus haut pourcentage de peau et de gras que les Barbaries. Ces derniers ont démontré un taux de viande et d'os significativement

(P<0.05) plus élevé que les Pékins. A l'intérieur de la race Pékin, les canetons nourris de diètes formulées à partir de déchets alimentaires ont démontrés un pourcentage de peau et de gras significativement (P<0.05) plus élevé que les cannetons nourris avec la diète contrôle. L'analyse du gras sous-cutané a démontré une différence significative(P<0.01) dans les profiles d'acides gras chez les 2 races. La différence la plus remarquable est la plus grande proportion d'acides gras monoinsaturés retrouvée dans le profile des Pékins (51.79 vs 9.61 %); cependant le profil des Barbaries contient un pourcentage d'acides gras polyinsaturés significativement (P<0.01) plus élevé (35.60 vs 17.41 %) que le Pékin. En plus du maïs et du tourteau de soya, 9 autres ingrédients provenant des déchets alimentaires ont été testés pour leurs valeurs nutritionnelles. La technique de prise alimentaire déterminée a été utilisée pour établir la digestibilité de la matière sèche, du gras, et de la fibre, la rétention de l'azote et les valeurs de EMA, EMAn, EMV, EMVn, pour les onze ingrédients. Les arachides avaient le plus haut (P<0.01) taux d'énergie, suivies de pogo, granola, tofu, diète de déchets alimentaires, pain, maïs, tourteau de soya, drèche de brasserie, okara et peau d'arachides, avec des valeures respectives de 5195, 4195, 4019, 3967, 3498, 3220, 3216, 2357, 1829, 1712, et 1244 kcal EMAn/kg. La valeur de NDF du pain était significativement (P<0.05) la plus digestible (88.9 %), avec 96.29 % d'hémicellulose. Cependant, la valeur NDF de l'okara, similaire à celle des peaux d'arachide et du tourteau de soya, était significativement (P<0.05) la moins digestible (26.94 %) avec 14.38 % d'hémicellulose. Les résultats de cette étude établissent des données crédibles pour la formulation des diètes pour canards, à base des ingrédients de déchets alimentaires testés, du maïs et du tourteau de soya, et celà pour des cannetons Pékins et Barbaries, à deux âges de croissance différents.

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GENERAL INTRODUCTION

Throughout the world, there is a strong agreement over the necessity for enhancement of environmental protection to achieve a sustainable development. The global ecological imbalance and the irrational use of the natural resources continues to threaten life quality in the near future. In a well urbanized and industrialized society, one would feel satisfied with the well being of his or her community. However, the industrialized countries are the most responsible for the deterioration of the environment because of an unsustainable system of production and consumption. The world's growing human population is demanding more food production but both have to fall within the capacity of the earth's ecological systems. Rational patterns of consumption, production, and long term sustainability are required to absorb the devastating effects of the population growth and its consequences. The world reserve of grain today is only enough for less than 49 days (Brown, 1996) indicating the narrow margin of safety and uncertain future we could be left with and to which we are leading our children. In the United States, 70 % of the grain produced in 1990 was consumed by livestock (Durning and Brough, 1992). After being a net grain exporter of 8 million tons in 1994, China became a grain importer of 16 million tons in 1995 (Brown, 1996). This tremendous change in such a short time was necessary to accommodate the demand of its new intensive system of livestock production needed to feed the massive increase in the population. The world population is growing at 90 million persons a year which requires an increase in grain production of 25 million tons of grain or 78,000 tons a day (Brown, 1996). However, there are limitations to this increase in production represented by the limited arable land. That land has to meet both population growth accomodations: building cities and required agricultural demands. Furthermore, as the pressure to grow more food increases, soil erosion increases and fertility decreases. In addition, underground water tables are falling in many parts of the world by centimetres and sometimes in meters per year (Brown, 1996). In the past, the utilization of chemical fertilizers boosted productivity of the cropland, but now the soil response to fertilizers is declining. Pests, plant diseases, and weeds are developing resistance to their anti-chemicals which require new and more expensive formulas. Primitive livestock systems can no longer meet the need of the exploding population. Ruminants used to eat grass and crop wastes on farm, pigs and fowl ate crop wastes and kitchen scraps. Thus, these systems turned things that people could not eat into products people lived on. Now to satisfy the needs, valuable feedstuffs such as corn, wheat, and soybean suitable for human consumption are being used for animal production in the absence of an alternative. This alternative should be the third base of a triangle where the other two are production and consumption. Recycling or reusing of the industrial food wastes as animal feed results in many advantages favouring humanity and the environment. Traditional feed ingredients can be spared for human consumption, thus reducing the pressure on the soil and water reserves, and on air pollution. New industries and markets can be established and new jobs created. Low cost animal products will be more available for consumers at a time when annual consumption of meat in some countries does not exceed two kilograms because of the price. Air pollution in general and carbon dioxide emission in particular will decrease because less material will be sent to incinerators.

Despite the intensive research, numerous inventions and innovations in food processing technology, this industry continues to produce considerable amounts of valuable wastes the most of which, if not all, ends up in landfill or in better cases in compost. Instead, these industrial food wastes can be efficiently recycled into human food again through animal production. Finally, many industrial and institutional food wastes sent to garbage disposal facilities have better nutritive value than the food available for millions of people in the developing world.

LITERATURE REVIEW

Intensive work and research are currently under way in the world to maximize the production of protein products. Plant scientists are concentrating on producing plants richer in proteins and enriching these plants with essential amino acids aiming at higher quality protein. Animal nutritionists are effectively transforming this plant protein as well as non-protein nitrogen into animal protein. Although hope is relying on selection and production of new or improved varieties, immediate alternatives such as feeding non-conventional feedstuffs to animals is one of the potential solutions.

A-ANIMAL SPECIES

Feeding industrial and institutional food wastes to producing animals could be most effectively achieved with the swine, goat and duck species. Their performance is not affected by low quality feed and they can increase their feed intake enough to meet their nutritional requirements. The duck as a smaller biological animal unit and shorter production phase gives more flexibility to the size of the production unit which could be adjusted accordingly. There are two breeds of ducks that are economically successful meat producers: the common duck (Anas platyrrhynchos), with the Pekin being the most important commercial breed, and the Muscovy (Cairina moschata).

a-Origin

All domestic ducks except the Muscovy, are descended from the wild mallard and were first domesticated in Southeast Asia or China. Today 18 breeds are recognized in the UK (May and Hawksworth, 1982) and 14 in the US (American Poultry Association,1989) where the White Pekin is the most common. The Muscovy originated in South America, the domesticated form being similar to, but larger than the wild species. Its tropical origin may explain the lower carcass fat content compared to the Pekin in which a higher carcass fat content is advantageous in cooler climates.

b-Characteristics and Differences of Pekin and Muscovy Ducks

There is an increasing interest in the growth potential of meat type ducks, especially since their overall performance is often better than that of chickens with carcass quality represented by the considerable deposition of subcutaneous fat as the major limitation . Ducks eat to meet their energy requirement, so that a low protein to energy ratio will lead to an increase in fat deposition. Consequently, energy:protein ratio must be seriously considered when formulating duck rations. Ducks respond to E:P ratios similarly to broiler chickens and turkeys where a lower E:P ratio diet results in less carcass fat deposition. Most importantly, ducks are believed to possess a greater potential to digest fibre than do chickens; hence, their metabolizable energy values for feedstuffs are 5-6% greater than corresponding values for chickens. This crude fibre utilization, however, requires verification. The carcass abdominal fat in ducks represents 2% of body weight, which is similar to that found in broiler chickens, while the subcutaneous fat remains the problem since it cannot be removed during processing (Leeson and Summers,1997).

Performance differences between the Pekin and Muscovy species show a sexual monomorphism in the former and a clear dimorphism in the latter. The market weight of male and female Pekins, at 7 weeks of age, is 3.3kg and 3.1kg, respectively, and that for male and female Muscovies is 5kg, at 12 weeks of age, and 2.5kg,at 10 weeks of age, respectively. Feed efficiency at these market ages is similar regardless of species and sexes. However, carcass composition comparisons reveal more protein and less fat in the Muscovy than in the Pekin in spite of the lower protein requirement of the Muscovy (Leclercq et al,1985).

Both duck breeds are characterized by having growth rates that are relatively insensitive to the energy density of the diet even for diets with considerably low energy value, due to the flexibility of these birds in regulating feed intake to meet their energy requirements, (Larbier and Leclercq, 1992). This is due to the high intake capacity of ducks as opposed to chickens which need diets relatively high and constant in energy density to perform well. Thus, in ducks, the dietary energy concentration to be adopted is quite flexible, and should depend on which energy source has a lower cost. This feature also makes this species particularly adaptable to diets of fluctuating composition and quality. When offered diets that vary widely in metabolizable energy (ME) content, ducks show remarkable ability to adjust their feed intake so that their ME consumption is relatively constant (Dean, 1986a, Siregar et al, 1982).

In addition, ducks have a small intestine that can absorb salt using a specialized mechanism when dietary intake is high. This excess salt is then excreted by nasal salt glands (Moran, 1986).

Another remarkable feature of ducks is their exceptional capacity for compensatory growth, often shown in studies on protein requirements. Dean (1972a) found that White Pekin ducklings fed 16 % crude protein (CP) diets from hatching to market age (6 to 8 wk) achieved normal body weight by market age. In doing so, the ducklings were able to overcome a growth depression of up to 30 % at 14 days of age. This is also of interest for the purpose of feeding diets based on food wastes. Since the composition of some of these wastes is quite variable, reliable information on their energy value and protein content is often unavailable. This makes it difficult to formulate diets to guarantee a certain protein allowance with some degree of precision. However, being able to compensate effectively after periods of possible protein deficiency, ducks are the favourable choice to perform well on this type of diet and to achieve an efficient conversion of the food wastes into good quality animal protein.

The only problem for ducks with feeding systems based on wastes may be the sensitivity of ducks to mycotoxins. The first bioassay method to determine aflatoxin in feeds was developed based on day-old ducklings (Sargent et al, 1961). Ducks are very sensitive to aflatoxin B1, the most common compound of this family of toxins. The dose of aflatoxin B1 that causes growth depression in ducklings is only 100 μg/kg diet, 10 times lower than that for the chicken (Bryden, 1982).

B-DUCK NUTRITION

Ducks are less important than broiler chickens, laying hens, and turkeys in the poultry production of the developed world. For this reason, little research has been done on the nutrition of this species, and formulation of diets for ducks depends on data reported for other poultry species. However, this can only be appropriate in certain cases because there are some differences in the digestive physiology between ducks and chickens (Elkin, 1987).

Ducks raised for meat production are generally fed starter, grower, and finisher diets during their growing period and require a high-quality diet for the first two weeks of age.

a-Energy and Protein Requirements

Being characterized by their capacity for compensatory growth, Pekin ducklings were able to reach maximum body weight and overcome a 30 % growth depression at 14 days of age (Dean, 1972a). Siregar et al (1982a) grew Pekin ducklings from day-old to 14 days after hatching on diets containing 3035 kcal ME/kg and a range of crude protein (CP) contents from 18 to 24 %. Growth rate and feed efficiency were not affected, but as percent CP declined, carcass fat increased. Different combinations of dietary CP were used in formulating a starter diet fed from 1 to 14 days of age and a grower-finisher diet fed from 15 to 56 days of age. Feed efficiency was the same on all diets, but the highest growth rate was achieved dy feeding 18.7 % CP throughout the growth trial (Siregar et al (1982a).

Following their first experiment, Siregar et al (1982b) fed ducks from 2 to 8 weeks of age on diets that varied in protein and energy levels. Dietary CP as little as 12 % showed no significant effect on growth rate or feed efficiency to 56 days of age. In a similar study, however, Dean (1986a) observed low yield of feathers and cannibalistic feather pecking on low protein diets. Siregar et al (1982b) performed an experiment with mixed sexes of White Pekin ducklings. The main effects showed that although growth rate on diets with ME of 2748 to 3512 kcal/kg, was the same, the highest growth rate and the best feed efficiency were achieved on the two diets with 3250 and 3512 kcal ME/kg.

Leeson and Summers (1997) set dietary specifications for Pekin ducks diets to contain 22.5 % CP and about 2800 kcal ME/kg for starter and 18 % CP and approximately 2900 Kcal ME/kg for the grower-finisher diet.

For optimal early growth, Scott and Dean (1991) reported that typical diets for Pekin ducklings from day 1 to 2 weeks of age require 22 % CP and 3080 kcal ME/kg. Although ducklings are characterized by their capacity for compensatory growth, a lower protein percentage of the diet would usually lead to the same finishing growth. Thus, 22 % CP in the starter ration is necessary for feather development, to aid coping with stresses and to minimize heat loss. In the growing and finishing phases of growth, Pekin ducklings require diets containing 16-18 % CP and about 3050 kcal ME/kg for optimal growth (Scott and Dean, 1991).

The NRC (1994) recommends for the starting period a 22 % CP level with 2900 kcal ME/kg, and for the growing -finishing period a 16 % CP level with 3000 kcal ME/kg.

Between 1975 and 1985, Muscovy ducks gradually replaced Pekin ducks in France (Stevens and Sauveur, 1985) following the genetic program of Joseph Grimaud to improve the carcass quality of Muscovy ducks. Before that time, there were no data on the requirements of Muscovy ducks for protein and metabolizable energy. Data from other species like chicken and turkey were being used (Leclercq and de Carville, 1985).

Considering the Muscovy carcass properties characterized by low fat and large breast muscle, it is expected that their dietary protein level must be relatively higher than their dietary energy when compared to Pekin ducks requirements (Scott and Dean,1991). However, Leclercq and de Carville (1985) studied the protein requirements of starting (0-3 wk of age), and growing-finishing (4-10 wk of age) periods. Ducklings were fed isocaloric corn and soybean basal diets at approximately 2952 kcal ME/kg, and were offered 5 levels of dietary protein ranging from 17.7 to 24.5 % CP. Protein requirements were determined separately for males and females because of their sexual dimorphism. For the starting period, maximum weight gain was achieved at 19.3 % CP in males and at 17.7 % CP in females. For the growing-finishing period, the Muscovy males and females required 15 % CP for maximum weight gain between 4 and 6 weeks of age, after which their CP requirement decreased to 13 %. Leclercq and de Carville (1985), conducted a study on female Muscovies from hatching to 10 weeks of age being fed diets varying in energy levels from 2490 to 3170 kcal ME/kg. The protein level of these 5 diets was maintained at 19.3 % CP so that their ME:protein ratio varied from 12.9 to 16.4. Their results showed that although weight gain was not statistically significantly affected, there was a negative correlation between the level of energy and the feed:gain efficiency ratio.

In general, the remarkable flexibility of ducks for feed consumption enables them to achieve normal growth on low-energy feed (Scott et al, 1959). The ducks were fed a range of 2420 to 2970 kcal ME/kg diets and still maintained near normal weight gains. These results agree with those reported by Dean (1978) who fed various levels of cellulose as an energy diluter of the diet. This dilution of the basal diet set a metabilizable energy range of 2200 to 3080 kcal/kg. Body weight gain was not affected by the different dietary levels of cellulose ranging from 5 to 40 %. The cellulose was assumed to have no energy value for ducks. Ducks are superior to chickens in this ability to cope with low levels of energy in the diet,because of their capacity to increase feed consumption to maintain a constant ME intake. Hill and Dansky (1954) conducted a study on chickens fed diets containing up to 40 % dilution with indigestible oat hulls. The birds were not able to consume enough of the 40 % diluted diet and thus could not maintain normal growth.

b-Water

Water is of special importance for ducks when compared to chickens. Water:feed ratios were 4.1:1 and 2.3:1 for ducks and chickens, respectively when offered ad libitum (Siregar and Farrell, 1980). The authors postulated that the ducks need a high level of water consumption to facilitate the rapid passage of feed through their digestive tracts and also because they have high level of feed consumption. The crop of the duck is simply an enlargement of the oesophagus when compared to the more elaborated chicken crop where feed is stored. The widening of the oesophagus rather than a crop is probably responsible for the faster rate of passage of ingesta in ducks than in chickens of similar age fed identical rations (Elkin, 1987). Dean (1985) reported a water:feed ratio of 5:1 on a weight to weight basis. This high water consumption has also been interpreted to be a reflection of an inherent characteristic of ducks to filter water for feed residues (Farrell, 1990).

c-Fibre

The ability of ducks to digest fibre has been addressed by many researchers and still requires further investigation (Muztar et al, 1977; Siregar and Farrell, 1980a; Mohamed et al, 1984). Siregar et al (1982c) concluded that neither chickens nor ducks were able to digest acid detergent fibre. Ducklings grown from 2-7 weeks of age on isoenergetic diets with different levels of dietary fibre had normal gain and carcass weight. However, the results were not consistent for chickens, with dietary fibre inducing a positive or a negative effect in different experiments. For both ducks and chickens, Siregar et al (1982c) reported that as dietary fibre was increased, body fat decreased and that there was a tendency to increase protein in the carcass.

d-Fat

Animal fats, vegetable oils and animal-vegetable fat blends are usually used in diet formulations for ducks. These fats, when used in well balanced rations, have been shown to improve growth performance and feed efficiency without affecting the carcass quality or its flavour (Scott and Dean, 1991). However, growth depression, anemia and death were induced in ducklings fed diets containing 25 % rapeseed oil. The same level of soybean oil induced no toxic effect, but increased carcass fattening. The authors reported results from other workers indicating a fishy flavour in ducks fed a relatively high level of fish oil.

e-Diet Form

Ducks have been found to perform better on pelleted than on mash diets. Heuser et al (1951) indicated 29 % improvement in growth rate of ducklings fed pelleted feed when compared to the group fed mash feed. Dean (1985) reported that ducklings fed pelleted diets had 13 % more weight gain and required 10 % less feed per unit of live weight compared to the ducklings fed mash feed. Ducks were able to maintain normal weight gain on pelleted diets with ME levels ranging from 2200 to 3300 kcal/kg provided the appropriate energy to protein ratio was maintained (Scott and Dean, 1991). However growth rate was reduced on a mash diet containing 2600 kcal ME/kg which may indicate the birds' inability to consume enough of the mash feed to meet their energy requirement for normal growth . Fines in the pelleted feed have been found to have no effect on the duck's performance. levels of 0, 2, 8, and 16 % of fines in the pelleted feed were fed to ducklings from 0-24 days of age. The results revealed only 2 % and 3 % depressions in weight gain and feed conversion, respectively, on the diet that included 16 % fines (Scott and Dean, 1991).

C-NUTRIENT REQUIREMENT

a-Amino Acids

Some amino acids can be limiting factors in growth of ducklings by their absence or presence in inappropriate percentages for protein synthesis, leading to a reduced nitrogen balance. Since the amino acid profile of proteins of different poultry species varies little in terms of percentage of carcass composition, the amino acid requirements of growing market ducks can be estimated from those of broiler chickens because of the extensive data collected from chickens.

Amino acid requirements for ducks have concentrated mainly on the most limiting ones in a common diet. Diets formulated to meet protein requirements of ducks using conventional feedstuffs have always been shown to supply sufficient levels of essential amino acids except for the sulphur amino acids and lysine. Dean and Shen (1982) fed a 22 % protein diet and reported 10 % less weight in 2 wk old ducklings compared to those supplemented with 0.1 % methionine. In addition to improving growth performance, methionine supplementation increased the protein content of the carcass and reduced its fat in 10 day old ducklings (Scott and Dean, 1991). Less carcass fat, improved feathering with reduced cannibalistic feather pecking, and improved feed efficiency were observed during the growing-finishing period of Pekin ducks when the basal corn-soya diet was supplemented with methionine (Scott and Dean, 1991). These authors suggested approximately 0.35 % methionine in the grower-finisher duck diet for the best results. Elkin et al (1986) studied the methionine requirement for male Pekin ducklings and suggested a methionine range of 3.8 to 4.2 g/kg or a total of sulphur amino acids of 6.7 to 7.1 g/kg in a diet containing 22 % CP. Leclercq and de Carville (1977) investigated the methionine requirement during the growing (3-6 wk) and finishing (6-10 wk) periods of Muscovy males. Graded levels of methionine were added to the basal diet that originally contained 15.5 % CP, 0.3 % cysteine, and 0.25 % methionine. Supplementation with 0.05 % methionine maximized the weight gain. These researchers recommended 0.30 % methionine requirement which is 1.93 % of the protein and 1.0 g/1000 kcal ME during the growing period and 0.25-30 % methionine during the finishing period. Scott and Dean (1991) presented studies conducted by some workers on the beneficial supplementation of sodium sulfate on growth and feed conversion in ducks. The responce was explained by the sulfate sparing cysteine and methionine from being utilized in the biosynthesis of taurine and sulfated mucopolysaccharides.

Lysine, the second limiting amino acid for poultry growth, is generally included at 12 g/kg in a starter diet when the ME is 3010 kcal/kg (Farrell, 1990). Supplementing with lysine to exceed maximum growth requirement has shown to reduce carcass fat and improve lean tissue deposition (Farrell, 1990). Scott (1986) indicated the lysine content of Pekin carcass protein to be approximately 5 %. This low level of lysine compared to that of chickens (9.5 %), turkeys (10 %), and pigs (8.6 %) suggests that the lysine requirement of Pekins is relatively low, as a percent of the protein requirement (Scott, 1986). When diets are low in soybean, the main source of lysine in a practical diet, lysine supplementation has been reported to be beneficial. However, a corn-soy diet containing 14.6 % protein and 0.7 % lysine showed no improvement in Pekin growth because the lysine content of this diet is already 5 % of the protein (Adam et al, 1983).

Avian species, including ducks, are uricotelic where uric acid is the nitrogen end product of excretion. They lack the urea cycle and require arginine in their diet. Practical ingredients commonly used in starter diets usually provide sufficient amounts of arginine. The only experiment that investigated the arginine requirement performed by Chen and Shen (1979) was on mule ducklings (the hybrid of Pekin and Muscovy) during the starting period. For maximum growth, the investigators recommended 1.08 % arginine (5.88 % of protein, 3.48 g/1000 kcal ME) in the diet.

The amino acid requirements for duck finishing diets decrease by more than 25 % due to the relative increase in fat and reduction in lean deposition during the finishing period (Farrell, 1990).

b-Vitamins and Minerals

Vitamins and minerals play a vital role in the bird's metabolism because they are involved in almost every biochemical reaction and pathway.

α-Vitamins

Ducks have more rapid growth than chickens and hence their vitamin requirements are expected to be higher, especially for vitamin A and nicotinic acid (Farrell, 1990). NRC (1994) sets the duck requirement for vitamin A to be 2500 IU per kg of diet. Vitamin A deficiency has been associated with poor growth, muscular weakness, retardation of endochondral bone growth, and ataxia leading to paralysis and death (Scott and Dean, 1991).

No studies have been conducted to determine the vitamin D requirement in ducks since the 1940's. NRC (1994) suggests 400 IU per kg feed. A deficiency of vitamin D in ducks has been associated with rickets determined by reduced bone ash. Rickets can also result from calcium and phosphorus deficiency as well as the lack of any of the enzymes responsible for the conversion of the dietary vitamin to the active metabolite 1-,25-dihydroxycholecalciferol (Scott and Dean, 1991).

The vitamin E requirement for ducks was set using the degree of myopathy of the skeletal muscle induced by a deficiency (Dean, 1985). This deficiency was affected by dietary selenium, other antioxidants, and the level of polyunsaturated fatty acids in the diet (Scott and Dean, 1991). Vitamin E deficiency in chickens and ducks does not induce the same disorders. The major symptom of vitamin E deficiency in chickens is encephalomalacia which has not been observed in vitamin E deficiency in ducks. The NRC (1994) requirement for vitamin E in ducks is 10 IU/kg of feed. However, supplementing selenium at 0.1 ppm has been reported to prevent muscular dystrophy with vitamin E (1.2 mg/kg) deficient diets (Scott and Dean, 1991). The muscular disorder of the skeletal, heart, and gizzard muscles has been prevented also on a very low selenium diet supplemented with vitamin E (Scott and Dean, 1991). This vitamin E and selenium interrelationship lies in their joint action against the reactive oxygen species that lead to the oxidation of cellular organelles. Thus the requirement of vitamin E has to take into consideration the selenium level and the various stresses that the bird might be subjected to.

Vitamin K is affected by heat during pelleting of duck feed (Scott and Dean, 1991). This factor and the use of some drugs such as sulfaquinoxaline (a vitamin K antagonist that sterilizes the gut, depriving the animal of the microorganism source of vitamin K) have to be accounted for in supplementing a diet with vitamin K. The NRC (1994) recommends 0.5 mg/kg of feed.

Thiamine, pantothenic acid, pyridoxine, and riboflavin are sufficiently provided to ducks by a practical diet composed of natural poultry feedstuffs (Scott and Dean, 1991). Supplementation according to NRC (1994) provides a safety margin especially because no deficiencies of these vitamins have been reported except for thiamine due to the presence of thiaminase in diving ducks that feed live on raw fish (Scott and Dean, 1991). There are no NRC (1994) recommendations for thiamine and vitamin B_{12}. For pantothenic acid, pyridoxine, and riboflavin, the NRC (1994) recommendations are 11, 2.5, and 4 mg/kg diet, respectively.. Leeson and Summers (1997) recommend 2 and 0.01 mg of thiamine and vitamin B_{12} per kg diet, respectively. Vitamin B_{12} has to be added to a corn-soy diet that lacks the natural sources of this vitamin (Scott and Dean, 1991).

Niacin is vital in the nutrition of ducks because they have a high requirement for this vitamin for growth and the prevention of leg bowing. In a series of studies, Heuser and Scott (1953) demonstrated that with four dietary treatments, only the ducks receiving the niacin deficient diet exhibited bowed legs. In a subsequent study, they showed that niacin alone was able to reduce leg bowing to 45 %, when supplemented at 22 mg/kg of diet, compared to the 100 % incidence in the ducks receiving the basal diet. Niacin status is mainly affected by the poor availability of the bound form (niacytin) from most feedstuffs, due to destruction by intestinal microflora and the possible existence of anti-niacin compounds in some feedstuffs. Furthermore, there is a poor conversion of tryptophan to niacin due to the very high level of the enzyme picolinic acid carboxylase responsible for the conversion of tryptophan to carbon dioxide and water instead of niacin (Scott and Dean, 1991). The NRC (1994) recommendation for niacin is 55 mg/kg diet.

Biotin and folacin together were found to improve growth while that response was absent when one of them was missing (Hegsted and Stare, 1945). In addition to poor growth, folacin deficiency results in severe anemia. The NRC (1994) has no recommendation for biotin and folacin. Leeson and Summers (1997), and Scott and Dean (1991) suggest 0.2 and 0.15 mg/kg diet for biotin and 0.5 mg/kg diet for folacin, respectively.

Ascorbic acid can be biosynthesized in avian species because they do not lack, as humans do, the enzyme L-glucono-γ-lactone oxidase responsible for ascorbic acid synthesis. Despite this fact, Scott and Dean (1991) reported superior haemoglobin and erythrocyte values and greater bactericidal and lysosomal activities in ducks supplemented with vitamin C compared to the control ducks. Vitamin C has been shown to reduce the oxidation of vitamin E in the process of scavenging free radicals in a detoxification cascade that involves also glutathione peroxidase and reductase (Frei, 1994).

All these vitamin requirements were set high enough by NRC (1994) to account for any variation in requirements among breeds since different vitamins have been determined using different breeds of ducks.

β-Minerals

Poultry species and other animals require thirteen inorganic elements. In ducks, eight have been studied including calcium (Ca), phosphorus (P), chloride(Cl), sodium (Na), magnesium (Mg), manganese (Mn), zinc (Zn), and selenium (Se). Potassium (K), iron (Fe), copper (Cu), molybdenum (Mo), and iodide (I) are the other five. Except for I, the other 4 minerals are sufficiently supplied in commonly used feedstuffs for ducks (Scott and Dean, 1991).

Deficiency in Ca, P, and/or vitamin D in ducklings leads to bone deformation resulting in rickets. An excess of Ca or P can also be detrimental as it disturbs the ratio of Ca:P which must be maintained constant. In the case of P excess, P excretion increases and Ca^{++} excretion decreases or Ca^{++} reabsorption increases to maintain a constant ratio. In that case, if only the requirement level of dietary Ca is provided, Ca^{++} mobilization follows in an attempt to keep the ratio constant while the damage has already occurred. Thus, an appropriate Ca:P ratio should be considered in supplementing the duck diet. Dean (1985) indicated that the best growth of ducklings (0-4 wk of age) was at a Ca level of 0.56 % of the diet, while rickets were detected in ducklings fed diets with 0.17 % Ca. The same researcher's results showed growth depression of these ducklings when their diet was supplemented with 1.0 % Ca. The NRC (1994) recommends a Ca level of 0.65 % and 0.60 % per kg diet for the starting and growing-finishing periods, respectively. Dean (1972b) investigated the P requirement of Pekin ducklings (0-4 wk) at different levels of Ca. Poor growth, rickets, and mortality resulted from 0.35-0.45 % total P or 0.10-0.14 % available P. He also reported that these effects were magnified with the increasing level of Ca. Optimum growth and maximum bone ash were obtained at 0.60 % total P or 0.35 % available P (Dean, 1972). Muscovy ducklings required 0.40, 0.22, and 0.18 % available P during the periods 0-3, 3-6, and 6-10 weeks of age, respectively, for optimum growth (Leclercq and de Carville, 1979). The NRC (1994) recommends available P levels of 0.40 and 0.30 % for the starting and growing-finishing periods, respectively.

Corn-soybean meal diets cannot supply the ducks' demand for sodium and chloride which therefore need to be supplemented. One hundred % mortality occurred by the 19th day in ducklings fed diets without NaCl, and 0.2 % NaCl supplementation to the basal diet reduced this mortality to normal (Dean, 1985). The author suggested dietary levels of 0.14 % Na and 0.12 % Cl for optimal early growth. Excess NaCl of 1 % depressed growth and increased mortality among ducklings (Dean, 1985). The NRC (1994) suggests 0.15 and 0.12 % Na and Cl, respectively.

Ducks require 500 mg of Mg per kg of feed (NRC, 1994), and a normal duck diet provides about 3 times this amount of Mg (Scott and Dean, 1991). Deficiency of Mg induces retarded growth, convulsions, uncoordinated movement and death (Van Reen and

Pearson, 1953).

Bernard and Demers (1952) induced Mn deficiency in a semi-purified diet based on casein, skim milk, and corn containing 0.5 mg/kg Mn. Low growth rate and perosis were observed after 10-15 days. Normal growth and prevention of perosis were supported by supplementing the diet with 15 mg Mn per kg feed. Although some workers reported little response of mule ducks to 20 mg Mn/kg, Dean (1985) reported results of his work and others' indicating that 18 mg Mn/kg was found to be marginally deficient for Pekin ducklings. The NRC (1994) suggests 50 mg for the starting period with no value set for the growing-finishing period.

Selenium requirement in the diet has been discussed with vitamin E as antioxidants. Feedstuffs grown on soil low in Se has to be supplemented with Se to assist vitamin E in scavenging free radicals and avoiding muscle necrosis, depressed early growth, and high mortality (Dean and Combs, 1981). While no estimates were provided for the Se requirement during the growing-finishing period, the NRC (1994) recommends 0.20 % Se for early growth.

Iodide requirement is estimated from chicken data since there is no indication of a greater demand. Thus, 0.5 and 0.4 mg I/kg of diet is suggested by Scott and Dean (1991) and Leeson and Summers (1997) respectively.

Potassium, Fe, Mo, and Cu are sufficiently supplied by the common feedstuffs used to formulate diets for ducks (Scott and Dean, 1991).

D-CARCASS COMPOSITION AND CHARACTERISTICS

Ducks have a greater ability for voluntary energy intake than other poultry species. That intake is associated with a greater deposition of fat, mainly subcutaneous. However, duck meat has been reported to have less cholesterol than the other poultry species (Scott and Dean, 1991). As human diets are being blamed for various health disorders, consumers are demanding meat products low in fat and high in protein. Researchers and producers are faced with the changing preference of consumers and hence have to work on the factors that influence carcass composition to render it reasonably acceptable.

a-Genetic Factors

White Pekin and White Muscovy ducks not only differ in their growth rate , but also in their carcass composition. The Muscovy breed possesses more lean tissues and less subcutaneous fat than the Pekin. Cross breeding of these ducks has been used as a tool to modify carcass composition. Crossing Pekin with Muscovy produced a carcass lower in fat, but the duck resulting from this cross is an infertile mule duck (Abdelsamie and Farrell, 1985). This hybrid had 17.0 % skin plus fat and 14.6 % muscle compared to pure Pekin with 26.6 % skin plus fat and 12.9 % muscle. Abdelsamie and Farrell (1985) reported increases of 16.2 % in breast muscle thickness, 6.9 % in live weight, and 5.1 % in the proportion of breast in the carcass due to selection compared to unselected controls. However, carcass composition of ducks is correlated to body size which in turn is associated with reproduction traits such as the number of eggs laid per laying period (Scott and Dean, 1991). Thus, selection for more lean tissues depending on body size results in an even higher proportion of fat and a reduction in number of eggs (Scott and Dean, 1991). From 25 years data collection on Pekin ducks, these authors indicated 49 g and 31 g increases in skin-fat and total muscle, respectively, for each 100 g increase in eviscerated carcass weight.

Increased carcass fatness has resulted from increasing growth rate as a consequence of improved housing, management, selection, and nutrition. The undesirable fat can be dealt with by relative genetic selection for leaner ducks with the new technologies available such as the use of ultrasound, and the application of the appropriate nutritional principles, mainly the proper energy:protein ratio.

b-Dietary Factors

Carcass composition is influenced by many dietary factors, the most important being the energy to protein ratio. Feeding isoenergetic diets (3035 kcal ME/kg) with varying CP levels from 18 to 24 % produced 14-day-old ducklings possessing 18 to 12 % carcass fat having fixed intake, growth rate, and feed efficiency (Siregar et al, 1982a). When dietary CP in the starter was below 22 %, carcass fat was higher in the birds on these diets at 56 days of age, and changing the CP level in the finishing period has not shown to be effective. Abdelsamie and Farrell (1985) reported that decreased fat and increased protein in the carcass were observed with dietary protein above 18.5 %. White Pekin ducklings were grown to 56 days of age on various combinations of energy and protein levels (Siregar et al, 1982b). As the ratio of energy :protein (kcal:%) increased from 12 to almost 28, there was a decline in carcass protein and an increase in carcass fat in both sexes.

Feed restriction has been shown to influence carcass characteristics in many species. Campbell et al (1985) investigated the effect of feed intake on carcass weight and fat of ducks grown from 14 to 56 days of age. As intake increased, there was an increase in growth rate and carcass fat, and a decrease in the protein content of the carcass. At 56 days of age, carcass fat showed more response to change in feed intake than did growth rate. Eighty percent of ad libitum intake reduced carcass fat by 23 %, but carcass weight by 12 % only.

Increasing dietary fibre reduced fat and increased protein in the carcass of ducklings maintaining a constant growth rate (Siregar et al, 1982c).

E-METABOLIZABLE ENERGY BIOASSAY

a-Apparent and True Metabolizable Energy:

There are many important reasons for the determination of the metabolizable energy values of feed ingredients used in formulating diets for poultry. These reasons include balanced formulation of rations where energy is the reference component, and efficient utilization of feedstuffs when feed accounts for approximately 60 % of the production cost. On the same path, determination of nitrogen retention is as important for the same reasons and others such as reducing nitrogen excretion for environmental concerns. Bioavailable energy of feedstuffs represents 70 % of the 60 % cost and hence is 40 % of the cost of feed (Sibbald, 1982c). As mentioned previously, the duck's consumption of feed is associated with its need to satisfy its energy requirement. As ME of the diet decreases, feed intake increases. This negative association between the diet ME and feed intake led to considering energy as the common denominator in feed formulation relative to which the other nutrients can be included in the diet at fixed ratios to control their intake (Crampton, 1964).

Apparent metabolizable energy (AME) bioassay accounts for the faecal and urinary energy voided by the bird fed the feed ingredient to be tested. However, the true metabolizable energy (TME) bioassay considers, in addition to AME, the energy voided by the bird in a fasting state or when fed a protein-free diet in order to account for the endogenous excretion. By doing so, TME provides a more reliable estimate of the real energy value, especially when each bird is used as its own control of the metabolic faecal and endogenous urinary excretion that reduces experimental variation (Sibbald and Price, 1980).

AME and TME are calculated according to the following formulas:

$$AME = IE - (FE + UE)$$

$$TME = AME + (FmE + UeE)$$

Where,

IE : is the ingested energy.

FE + UE : is the energy voided in the excreta by the fed bird.

FmE + UeE : is the energy voided in the excreta by the fasting bird.

Uric acid is the end product of nitrogen catabolism in poultry species and hence affects the values obtained for AME or TME. Furthermore, during the bioassay, a bird can be in either a positive or a negative nitrogen balance (Sibbald, 1982). AMEn and TMEn are the values corrected to zero nitrogen balance and are calculated as follows:

AMEn = AME - (8.22 * ANR ÷ FI)

TMEn = TME - (8.22 * FNL ÷ FI)

Where,

8.22 : is the energy in Kcal/g of nitrogen retained in the body or voided as products of tissue catabolism

ANR : is the apparent nitrogen retention (g) calculated as the difference between N intake and N output.

FNL : Fasting nitrogen loss (g)

FI : Feed intake (g)

TME has an advantage over the other bioassays of energy determination of feed or ingredients by being independent of the type of experimental bird and feed input (Sibbald, 1982c).

Energy values used to formulate diets for ducks, are mainly adopted from tables of chicken bioassay data. However, evidence on the similarities of N and energy metabolism in ducks and chickens is equivocal. Siregar and Farrell (1980a) and Ostrowski-Meissner (1983) reported differences in the metabolizability of energy and N values obtained for several diets between chickens and ducks of the same age where ducks were significantly superior. In addition Muztar et al.(1977) suggested that ducks have a greater ability to digest cellulose than do chickens. Schubert et al.(1982) reported that Muscovy and Pekin ducks were more able to retain organic matter, crude fibre, crude protein, and nitrogen-free extracts than were laying hens. Mohamed et al.(1984) found that ducklings of 8 weeks of age obtained higher metabolizable energy (ME) values of feedstuffs than broiler chicks of 8 weeks of age only when fed diets rich in soybean meal and alfalfa meal while there were no significant differences between the two species in the ME values obtained for corn, wheat, and barley; furthermore, the ME value of cotton seed meal was significantly higher for the chicks than for the ducks. At the time that Schubert et al.(1982) reported that ducks showed digestibility values for crude fibre ranging from 0 to 36 %, Siregar and Farrell (1980a) and Mohamed et al.(1984) did not find great differences between the energy values in the diets for chickens and ducks, knowing well that chickens are almost unable to digest fibre. While many studies suggest the ability of palmipeds to digest grass efficiently, Cowan (1980) concluded that grass is poorly digested by geese. Carré et al.(1989) found that 73-day old cockerels and 60-day old muscovy ducks were only able to digest the water-soluble fraction of the nonstarch polysaccharides. Muztar et al.(1977) fed White Leghorn roosters and White Pekin ducks five species of dehydrated fresh water plants and dehydrated alfalfa. While their findings suggest no significant differences between the roosters and the ducks for two species of plants, ducks metabolized a considerable portion of the watermilfoil gross energy whereas the roosters could metabolize no energy from this plant species, and ducks had lower true metabolizable energy (TME) for the other 2 species. Dean (1978) reported that the growth rate of ducks to 48 days of age was not influenced by dietary energy concentration and that diets containing up to 490 g of cellulose/kg did not depress growth rate compared with those without any cellulose. In a study using growing ducklings, Siregar and Farrell (1980a) (whose findings support the fact that ducklings made more efficient use of dietary energy and protein than broiler chickens) reported that this capacity of metabolizing dietary energy decreased with age in ducks only.

It is not surprising to observe differences in the utilization of dietary energy between chickens and ducks since they have differences in growth rate, body composition, and in starvation heat production (Siregar and Farrell, 1980b). Confronted with all these controversies, we cannot see consistent similarities or differences in the feed utilization ability of chickens and ducks or between the duck species at different ages.

SECTION I

The effect of food-waste diets and breed on growth performance of Pekin and Muscovy ducklings

The objective of this study was to compare the growth performance of White Pekin and White Muscovy ducklings from day-old to their market age fed nutritionally balanced experimental diets based on chemical analysis of industrial food wastes.

The original idea to initiate this study was provided by Dr.E.R.Chavez and Dr.S.P.Touchburn. The research was supported by the Conseil des recherches en pêche et en agro-alimentaire du Québec.

ABSTRACT

Comparison of growth performance of Pekin and Muscovy ducklings fed diets based on food wastes

Three hundred Pekin and 300 Muscovy male ducklings were raised on diets based exclusively on food wastes from day-old to market ages of 7 and 11 weeks, respectively. Three dietary treatments were offered to the birds: commercial pellets (control), feeds consisting partially of food waste, and feeds consisting entirely of food waste. The two experimental treatments each had a dry pelleted diet and a wet mash diet offerred free choice. The control treatment provided 25.49, 23.34, and 21.33 % crude protein (CP) on a dry matter basis for the starting, growing, and the finishing periods, respectively . The treatment including partial waste had two rations for the dry diet containing 23.37 and 22.82 % CP for the starting and growing-finishing periods, respectively, whereas the wet diet had a single ration with 17.30 % CP on a dry matter basis. The treatment formulation with 100% food waste also had two forms of diets, dry pellets (18.04 % CP) and wet mash (20.69 % CP). Body weight was not significantly different ($P>0.05$) for the Pekin and Muscovy ducklings fed the diet containing partial food waste and the diet containing 100 % food waste when compared to the control diet . Both Pekin and Muscovy birds consumed less feed of the diets containing food waste than those on the commercial diet of the control. Feed efficiency was significantly better ($P<0.05$) for the Pekin breed and for the experimental dietary treatments for both breeds. However, the birds fed food waste diets consumed significantly higher proportions of fat and less protein due to the characterized chemical composition of the waste ingredients used in

the ration formulations. These results reveal the nutritional value of industrial food wastes as alternative sources of feedstuffs in animal agriculture.

INTRODUCTION

As a result of the continuous increase in the world population that has already exceeded 6 billion people, more cereals and animal products must be produced for human consumption. Today's systems of animal agricultural production put humans and animals in competition for grains. Alternative feeding systems are required to reduce this competition and to make use of the potential resources generated by the food industry as food wastes into valuable feed ingredients.

The possibility of separation, collection, and utilization of food wastes as feedstuffs for producing animals has been studied in many places in the world. Residential food waste was ranked second (31.7 percent) after paper waste (33.8 percent) in Illinois (Newton and Burger, 1994). Of the commercial establishments producing food wastes there, 83.3 percent accepted to separate the waste for collection at no extra cost and only 16.7 percent were willing to pay extra. The dinning hall of the residence at the University of Illinois generates about 1.5 tons per day of food and paper waste that is used in cattle feed production (Navarro, 1993). There is an increasing number of companies manufacturing equipment and offering services to transform industrial and institutional food wastes into animal feed and soil conditioners (Goldstein, 1995). In Hoorn, The Netherlands, 75,000 residents are being served by the collection of their kitchen and vegetative wastes where 29,400 metric tons of compost are generated (Shutte et al, 1991). Thirty tons of organic residuals were composted daily in Altoona, Pennsylvania, where food wastes were separately collected (Glenn, 1991) and could have been used as animal feed instead of being sent to compost. Some of these food wastes generated from households and the food industry have been partially incorporated into producing animal feeds. El Bouchy (1994) successfully fed diets including 50 percent food waste to laying hens in The Netherlands. Peanut skins included at a level of 10 % in calf diets improved their body weight by 27 % (Utley and Hellwig, 1985). Brewers grains contain protein which is undegradable by the rumen microflora and therefore bypasses the rumen, resulting in improved milk production in dairy cows (Cozzi and Polan, 1994).

Feeding food waste to producing animals could be most effectively achieved with the swine, goat, and duck species. Their performance is not affected by low quality feed because they can increase their feed intake to meet their nutritional requirements. In 1988, Canada was a net importer of about a million kg of graded duck carcasses (Agriculture Canada, 1988). Moreover, there is an increasing interest in the growth potential of meat type ducks, especially since their overall performance is better than that of chickens (Leeson and Summers, 1991). Although the White Pekin breed predominates in North America, the White Muscovy's popularity is starting to increase due to its high yield of lean meat. These two breeds have different growth rates and carcass composition. Therefore, it was of interest to evaluate and compare their response to the diets formulated on food wastes. The objective of this study was to compare the growth performance of White Pekin and White Muscovy male ducklings from day-old to their appropriate market ages fed nutritionally balanced experimental diets based on the chemical analysis of industrial food wastes.

MATERIALS AND METHODS

Experimental Animals and Management :

A total of 600 day-old male ducklings were purchased from local hatcheries, 300 White Pekin[1], and 300 White Muscovy[2]. The ducklings were weighed by groups of 25 and randomly distributed into 24 floor pens at $0.224 m^2$ per bird in a windowless, fan-ventillated building. They were housed on wood shavings litter under electric brooder lamps and confined within a cardboard ring of 45 cm height for the first week of age. The first two days, the ducklings were observed eating shavings. Therefore, feed and chick size granite grit were offered separately from the feed in the tube feeders, on egg flats during their first week. Water was supplied by automatic water bells, dry feed in hanging tube feeders having a capacity of $0.56 m^3$, and wet feed in plastic troughs having a capacity of $0.018 m^3$.

The birds received 24 hours of light for the first week and then 16 hours of light daily, from 4:00 am to 8:00 pm, for the rest of their growth period. Light intensity was progressively reduced as aggressiveness (feather pecking) by the ducklings was observed. All birds were declawed and the Muscovy ducklings were beak trimmed at the age of 2 weeks.

All ducklings were individually wing-banded and weighed at the age of 2 weeks.

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[1]Brome Lake Ducks Ltd., Knowlton, Quebec, Canada.

[2]Couvoir Simetin, St-Canut, Quebec,Canada.

Feed consumption was recorded at week 2, 4, 7, 10, and 11. The birds received dry feed starting day one. Wet feed was offered starting day 8. Feed and water were offered ad libitum and with free choice of type of feeds.

The temperature under the brooder lamp, during the first week of age, was 32°C and the ambient temperature in the building fluctuated between 28°C and 31°C for the first 2 weeks of age. For the rest of the growth trial, the ambient temperature ranged from 18.7°C (average lower temperature) to 25.7° C (average higher temperature). This ambient temperature was maintained by thermostatically regulated fans. The experiment was conducted starting May 7, 1996; White Pekin ducklings were sent to processing at the age of 7 weeks on June 25th, and the Muscovy at 11 weeks of age on the 23rd of July 1996.

Experimental Diets :

The day-old birds were divided into three experimental treatments. The control treatment consisted of commercial starter, grower and finisher rations in pellet form (Table 1.1). A second treatment (partial waste treatment) consisted of experimental diet formulated with a dry mix that contained approximately 50% food waste ingredients, and a wet mixed diet composed solely of food wastes. The dry diet was formulated for two main phases, a starter ration and a grower-finisher one. The third treatment (100% food waste treatment) also had 2 diets, dry and wet, but both consisted exclusively of food waste materials. The dry diets of the two experimental treatments were pelleted at the Macdonald Recycling Pilot Plant with a die size of 4.5mm in diameter. Emphasis in diets formulation was put on supplying the birds with enough protein to explore the feasibility of utilizing food waste without impairing the birds' growth performance and carcass characteristics.

The food waste composition of the experimental diets is presented in Table 1.2. The nutritional composition of the food waste ingredients is shown in Table 1.3.

The vitamin and mineral mix was added based on the dry matter content of the diets to meet or exceed the NRC (1994) nutrient requirements for ducks (Table 1.2).

The wet feed was offered to ducklings on a daily basis since it contained about 50 % dry matter only and was susceptible to fermentation and growth of undesirable microorganisms. The feed that was not consumed in 24 hours was weighed and discarded.

Table 1.1: Growth periods and rations of Pekin and Muscovy ducklings

Breed	Age in weeks		
	Starter	Grower	Finisher
Pekin	0-2	2-4	4-7
Muscovy	0-4	4-7	7-11

The duck's dependence on water is well documented and that dependence is due to physiological as well as behavioral characteristics. Therefore, to minimize water spillage, the height of the water bells was increased continuously as the birds grew. Wet wood shavings were removed daily and the whole pen shavings were changed weekly.

Ducklings which developed leg problems, the only disorder observed, were killed by cervical dislocation, the method approved by the Canadian Council on Animal Care (1984).

Statistical Analysis :

Statistical analysis of the results was performed using the general linear models (GLM) procedures of the SAS (1990) library. The model included the effects of the diet, animal breed, and interactions. The dependent variables were feed conversion, and growth parameters. Each pen (replicate) represented an experimental unit. The design was factorial with 2 breeds, 3 treatments, and 4 replicates per treatment per breed. The three treatments were compared and contrasted using Sheffe's multicomparison test because we had 3 treatments with 2 degrees of freedom allowing for two comparisons with a simple T-test. The mean square used to calculate the critical difference for Sheffe's test was the mean square error given by the GLM since the treatments effects were considered fixed and hence GLM procedure was appropriate.

The statistical model for the experiment is as follows:

$Y_{ijk} = \mu + \text{Treatment}_i + \text{Breed}_j + \text{Interaction}_{ij} + e_{ijk}$

Y_{ijk} = Feed conversion and body weight gain of the k^{th} observation in the j^{th} breed receiving the i^{th} treatment.

μ = The overall mean

Treatment_i = The effect of the i^{th} treatment where $i=1, 2,$ or 3.

Breed_j = The effect of the j^{th} breed where $j=1$ or 2.

Interaction_{ij} = The interaction of the i^{th} treatment and the j^{th} breed.

e_{ijk} = The error term associated with the k^{th} observation in the j^{th} breed receiving the i^{th} treatment.

Table 1.2 : Composition of the Experimental Diets

Ingredient	Partial waste			100% waste	
	Starter Pellet	Finisher Pellet	Wet Mash	Dry Pellet	Wet Mash
			%		
Granola	10.6	18.0	10.0	13.0	17.44
Bakery waste[a]	18.0	16.4	10.0	35.0	15.0
Pogo meat	3.0	8.5	25.0	-	25.0
Okara	3.0	5.0	14.44	-	-
Pogo	3.0	-	14.0	10.0	-
Peanut Skins	2.0	2.5	-	7.0	-
Peanut	3.0	2.0	-	-	-
Brewers grains	-	-	15.0	-	11.0
Noodle	-	-	10.0	-	-
Cereal waste	-	-	-	32.4	-
Tofu	-	-	-	-	20.0
Canned food[b]	-	-	-	-	10.0
Soybean meal	22.0	16.5	-	-	-
Corn	12.0	10.0	-	-	-
Barley	10.3	7.8	-	-	-
Wheat bran	2.5	2.0	-	-	-
Fish meal	4.0	3.0	-	-	-
Tallow	4.0	3.5	-	-	-
Alfalfa meal	-	2.5	-	-	-
$CaCO_3$	0.5	0.5	0.3	0.5	0.3
Ca_2HPO_4	1.8	1.5	1.08	1.8	1.08
NaCl	0.2	0.2	0.12	0.2	0.12
Vit.+Min. mix[c]	0.1	0.1	0.06	0.1	0.06
Total	100	100	100	100	100

[a]Bakery waste composed of 25 % cookies and 75 % bread
[b]Canned food include baked beans and lentils
[c]Mineral premix for ducks: Iron, 95 ppm (Ferrous sulfate, 36.8% Fe) $FeSO_4$ dry powder; Zinc, 60 ppm (Zinc oxide, 73 % Zn) ZnO; Copper, 8 ppm (Cupric carbonate, basic $CuCO_3$ 55% Cu); Manganese, 60 ppm (Manganese oxide MnO_2 55% Mn); Selenium, 0.2 ppm (Sodium selenite 45.6% Se), Na_2SeO_3; Iodine, 0.4 ppm (Potassium iodide KI 76.4 % I). To be added at 0.05 % of the diet.
Vitamin premix: vitamin A, 2,500 I.U.; vitamin D_3, 400 I.U.; vitamin E, 10 I.U.; vitamin K, 0.5 mg; biotin, 0.1 mg; folacin, 0.5 mg; niacin, 55.0 mg; pantothenic acid, 11.0 mg; riboflavin, 4.0 mg; thiamine, 2.0 mg; thiamine-HCl; pyridoxine, 2.5 mg; vitamin B_{12}, 0.01 mg; ethoxyquin or BHT or Santoquin, 100.0 mg. To be added at 0.05 % of the diet.

Chemical Analysis :

Samples of food waste ingredients were first collected from the producing companies, freeze-dried using a Virtis freeze-dryer[3], absolute dry matter was obtained using a vacuum oven[4]. The samples were ground to a powder[5] before being subjected to proximate analysis, the results of which are presented in Table1.4. Gross energy was measured using an adiabatic oxygen bomb calorimeter[6]. Crude protein was measured using a nitrogen analyzer[7]. Acid detergent fibre (ADF) was determined using the method developed by Van Soest and fat was ether extracted. The ash content was determined using a muffle furnace[8]. Calcium content was determined by flame atomic absorption spectrophotometry[9]. Phosphorus content was determined by the alkalimeter ammonium molybdate method (AOAC, 1984), the optical density being measured using a spectrophotometer[10] at 400 nm. Formulation of the diets was based on these analyses. Food wastes collected from their sources were subjected to minimal processing including

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[3]Virtis freeze dryer # 278341, Gardiner, New York, USA.

[4]National Appliance Company, Illinois, USA..

[5]Tecator grinder # 3260, Cyclotec, 1093 sample mill, Sweden.

[6]Number 1241, Parr Instrument Company, Moline Illinois, USA.

[7]Leco FP-428, Leco Corporation, St-Joseph, MI, USA.

[8]Model F-A1730, Sybron Thermolyne Dubuque, Iowa, USA.

[9]Model 2380, Perkin Elmer, Norwalk, CT 60521.

[10]Model DU-20, Beckman, Fullerton, CA 92713.

chopping with a rotating blade chopper[11] with a 0.5 cm screen for starter rations and 1.0 cm for grower-finisher rations. An appropriate waste ingredient was selected to act as a carrier for the vitamin and mineral premixes mixed in a Hobart mixer[12] (60 kg capacity). The feed was mixed in a Davis precision horizontal batch mixer [13]. All the feed was bagged and stored in a walk-in freezer and removed to a walk-in cold room 48 hours before feeding.

The proximate analyses of the commercial pellets[14], used as control, as well as those of the experimental pellets and wet mash diets are presented in Table 1.4.

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[11]Model D, W.J. Fitzpatrick Company, Chicago, USA.

[12]Model V1401 Hobart, Troy, Ohio, USA.

[13]Serial 4040-53-67, Davis, Bonner Spring, Kansas, USA.

[14]Meunerie Shur-Gain CPL, L'Ange Gardien, Québec, Canada.

Table 1.3 : Proximate analysis[a] of the waste ingredients used in the experimental diets on DM basis

Waste ingredients	DM %	FAT %	C.P. %	ADF %	Ash %	Ca %	P %	E kcal/kg
Peanut	95.61	52.70	28.58	13.1	2.72	0.25	0.64	6,634
Bread	89.31	3.65	15.79	1.01	1.88	0.02	0.17	4,387
Granola	88.36	9.60	6.51	0.79	1.31	0.06	0.14	4,811
Peanut skins	87.8	9.21	18.88	34.10	2.25	0.19	0.20	4,864
Cookies	84.92	3.49	11.47	0.00	1.34	0.11	0.25	4,249
Pogo meat	58.83	49.65	28.03	0.79	7.01	0.39	0.47	4,870
Pogo	56.04	22.95	19.95	0.78	5.18	0.29	0.26	5,068
Noodles	44.90	4.45	15.47	0.34	0.32	0.02	0.11	4,521
Tofu	35.64	27.21	61.58	1.21	3.96	0.29	0.89	6,267
Brewers grains	30.14	5.92	19.43	21.20	4.22	0.33	0.55	4,193
Canned food	29.31	2.28	22.83	8.23	7.57	0.11	0.29	4,058
Okara	23.29	12.73	32.89	15.71	3.84	0.28	0.50	5,468

[a] Proximate analysis was conducted at the Crampton Nutrition laboratory, Macdonald Campus of McGill University

Table 1.4. Nutritional composition of the 3 dietary treatments on dry matter (DM) basis

Nutrient	Commercial pellets			Partial waste			100% waste	
	Starter	Grower	Finisher	Starter	Gro-Fin	Wet	Dry	Wet
DM %	86.74	86.11	87.08	84.07	82.21	54.12	83.67	55.04
C.P.%	25.49	23.34	21.33	23.37	22.82	17.30	18.04	20.69
Fat %	4.07	3.72	5.54	10.01	14.52	8.84	7.53	9.14
ADF %	4.28	4.64	5.03	3.73	3.61	3.03	4.33	2.78
Ash %	6.12	5.48	5.33	6.32	5.77	5.49	5.95	5.63
Ca %	1.05	0.99	0.90	1.10	1.02	0.73	1.14	0.60
P %	0.73	0.81	0.73	0.80	0.70	0.82	0.68	0.64
GE kcal/kg	4,545	4,562	4,998	5,143	4,814	5,249	4,651	5,235

Proximate analysis was conducted at the Crampton Nutrition laboratory, Macdonald Campus of McGill University

RESULTS AND DISCUSSION

The live weights of Pekin ducklings at market age of 49 d were 3.570, 3.742, and 3.524 kg for the control fed with commercial pellets, the partial waste, and the 100% waste treatments, respectively (Table 1.5). There were no significant ($P > 0.05$) differences in live body weight due to dietary treatments. The three groups of birds were considerably heavier than the expected market body weight of 3.200 kg. The live weights of the Muscovy breed at 11 wk of age were 5.060, 5.147, and 5.180 kg for the control, partial waste, and 100% waste treatments, respectively (Table 1.5). This is much heavier than the expected market weight for Muscovy males which is 4-5 kg at 12 wk of age. Here also, the differences among dietary treatments were not statistically significant ($P > 0.05$). For the Muscovy ducklings, the control group was heavier than the 100% waste treatment group at 7 wk of age (Table 1.5). This may be due to the lower crude protein content (18.04 % C.P.) of the dry 100% waste diet (Table 1.4). However, at 11 wk of age, these birds were able to reach a live body weight which was non-significantly ($P > 0.05$) but numerically superior to that of the control birds. This remarkable capacity for compensatory growth validated their ability to perform well on diets consisting entirely of food wastes. In addition, the 100% waste treatment did not have a starter and grower-finisher ration in order to exploit the ability of the ducks for adaptation in intake and compensatory growth. These results agree with those reported by Dean (1972a). However, feather pecking and cannibalistic behaviour were observed in the birds receiving this diet for a short period (3-4 days). Dean (1986a) reported such activities among birds fed low protein diets.

The average feed consumption per bird by breed and treatment is presented in Table 1.6. These values are reported on a dry matter basis. This consumption is further detailed according to the form of the feed; either dry pellets or wet mash feed. There was no significant interaction ($P > 0.05$) between treatment and breed. Hence, it was appropriate to test for differences between treatments for feed consumption and differences between breeds for feed conversion. There were no significant differences ($P > 0.05$) among the dietary treatments or the breeds for feed consumption (Table 1.6). For feed conversion, the Pekin breed was significantly ($P < 0.05$) superior to the Muscovy breed, and the birds fed the experimental diets were significantly ($P < 0.05$) more efficient than those fed the control diet (Table 1.7) . Total feed consumption per Pekin duckling was 7.522, 7.169, and 6.805 kg for the control, partial waste, and total waste treatments, respectively (Table 1.6). The consumption per Muscovy duckling was 11.957, 11.487, and 11.673 kg for the control, the partial waste, and the 100% waste treatments, respectively (Table 1.6). Table 1.6 also presents the relative percent consumption of dry and wet feed. The values in parenthesis reveal the preference of the duck species for wet feed. It was observed during the growth trial that the birds were transporting dry feed in their beaks to the water bells, dipping the feed in water and then consuming it. That is explained by their need for a higher water to feed ratio when compared to the chicken (Dean, 1985; Siregar and Farrell, 1980). Table 1.6 also shows the difference in wet feed consumption between the two breeds. White Pekins consumed a higher wet feed percentage of their total feed consumption than did the Muscovy breed

. Muscovy ducklings voided excreta with less moisture than that of the Pekin birds. The shavings under the Muscovy water bells were always dryer than those under the Pekin waterers and they played with water less than did the Pekins. Total consumption of the major nutrients in the diets (Table 1.8), indicates that the ducks fed commercial pellets consumed more dry matter and crude protein than those fed the experimental treatments but the latter consumed more fat. Table 1.8 shows the relative percent consumption (in parenthesis) of the major nutrients per duck by breed and treatment. For both breeds, the birds on the partial waste treatment consumed about twice as much fat as the birds fed the control feed. That is mainly due to the characterized nutritional composition (Table 1.3) of the food waste ingredients used for the formulation of the experimental diets. Studies to determine the true metabolizable energy of these unconventional feed ingredients as well as the carcass evaluation are presented in the following sections of this thesis. They were conducted to establish appropriate data base for future feed formulation with food wastes according to the optimal calorie to protein ratio. This adjustment of the calorie:protein ratio could have a significant effect on performance and carcass quality. Siregar et al (1982b) reported that increasing this ratio had no effect on the growth rate, but the best feed efficiency was achieved at the lowest energy:protein ratio. Table 1.7 on feed to gain ratio indicates that the Pekin breed was significantly more efficient than the Muscovy whose maintenance requirements for a longer period resulted in less feed efficiency. Pekin and Muscovy ducks fed the experimental diets utilized the feed significantly ($P<0.05$) more efficiently than the birds on the control diet (Table 1.8). That can be explained by the effect of the higher relative percentage of fat consumed by the experimental birds. Furthermore, since feed intake in ducks is regulated by their energy requirements (Leeson and Summers, 1997; Scott and Dean, 1991), the birds fed the more energy-dense waste containing diets consumed less (although not significantly less), which is reflected in their lower feed to gain ratio.

Table1.5. Average body weight of ducklings by breed and dietary treatment

Treatment	Pekin (7wk)	Muscovy (7wk) (kg)	Muscovy (11wk)
Control	3.571 ± 0.03^{a}	3.365 ± 0.03^{a}	5.060 ± 0.04^{a}
Partial waste	3.743 ± 0.03^{a}	3.178 ± 0.03^{b}	5.147 ± 0.05^{a}
100% waste	3.523 ± 0.03^{a}	3.223 ± 0.03^{b}	5.180 ± 0.04^{a}

[a,b]Means within columns with no common superscripts differ significantly ($P < 0.05$).

Table 1.6. Average feed consumption on DM basis per duckling by breed at appropriate market age

Breed	Commercial (kg)			Partial Waste(Percent) (kg)			100%Waste(Percent) (kg)	
	Starter	Grower	Finisher	Starter	Grow-Finish	Wet	Dry	Wet
Pekin	0.703	1.977	4.842	0.244(3.4)	1.156(16.12)	5.769(80.5)	0.760(11.2)	6.045(88.8)
Total	7.522±0.11[a]			7.169±0.10[a]			6.805±0.10[a]	
Muscovy	1.956	4.160	5.841	0.648(5.6)	3.292(28.7)	7.547(65.7)	2.413(20.7)	9.260(79.3)
Total	11.957±0.27[a]			11.487±0.20[a]			11.673±0.25[a]	

Differences were not significant ($P > 0.05$)

[1] The numbers in parenthesis represent the percent consumption of each ration and form of the diet

Table 1.7. Feed : Gain ratio by dietary treatment and breed at appropriate market age

Treatment	Pekin (7 wk)	Muscovy (11 wk)
Control	2.38 ± 0.04^{bA}	2.65 ± 0.04^{bB}
Partial waste	2.16 ± 0.04^{aA}	2.49 ± 0.04^{aB}
100% waste	2.18 ± 0.04^{aA}	2.49 ± 0.04^{aB}

^{a,b}Means within columns with no common superscripts differ significantly ($P<0.05$).
^{AB}Means within rows with no common superscripts differ significantly ($P<0.05$).

Table1.8.Total consumption of the major nutrients per duckling by breed at market age

Pekin	DM (relative %)	C.P. (relative %) (kg)	Fat (relative %)
Commercial	7.522 (100.0)	1.673 (100.0)	0.3636 (100.0)
Partial waste	7.169 (95.3)	1.319 (78.8)	0.7023 (193.1)
100% waste	6.805 (90.5)	1.388 (83.0)	0.6097 (167.7)
Muscovy	DM (relative %)	C.P. (relative %) (kg)	Fat (relative %)
Commercial	11.957 (100.0)	2.715 (100.0)	0.5580 (100.0)
Partial waste	11.487 (96.1)	2.208 (81.3)	1.2100 (216.8)
100% waste	11.673 (97.6)	2.351 (86.6)	1.0281 (184.2)

CONCLUSION

These results demonstrate that Pekin and Muscovy ducklings can be successfully raised on diets formulated partially or totally with food waste ingredients. They also show that the duck species is a good choice to utilize food waste, especially wet feedstuffs because of their ability to adapt to differences in nutrient concentration. The body weight of the ducklings fed the experimental diets was similar to that of the control with weight higher to what is generally expected. The birds on the experimental diets consumed less than the control and exhibited better feed conversion due to the higher energy content in the diets formulated with food wastes.

SECTION II

The effects of diets based on food waste and the breed on the carcass yield and composition of Pekin and Muscovy ducklings

In section I of this thesis, the growth performance study showed no difference in body weight between the experimental treatments and the control. However, the experimental diets formulated with food wastes contained more fat and the ducklings on these diets consumed more percentage of fat than the control birds. The objectives of this study were to determine the effect of feeding nutritionally balanced experimental diets based on chemical analysis of industrial food wastes on carcass yield and composition of ducklings. Also, to compare the carcass yield, carcass composition, and fatty acid profiles of White Pekin and White Muscovy ducklings at 49 and 77 days of age, respectively.

The original idea to initiate this study was provided by Dr.E.R.Chavez and Dr.S.P.Touchburn. The research was financially supported by the Conseil des recherches en pêche et en agro-alimentaire du Québec.

ABSTRACT

Comparison of carcass yield, carcass composition, and subcutaneous fatty acid profiles of Pekin and Muscovy ducklings fed diets based on food wastes

Three hundred Pekin and 300 Muscovy ducklings were grown from day-old to market age receiving diets consisting partially or entirely of food waste. Twelve carcasses from each breed were subjected to analyzed for yield and composition to determine the effects of the experimental diets compared to those of the control (commercial pellets). The treatment effects on carcass yield were not significant ($P>0.05$), Pekin ducklings fed 100 % food waste diet showed a significantly higher ($P<0.05$) carcass yield than the Muscovies. Pekins had significantly ($P<0.05$) higher skin and fat % than the Muscovies, while the latter breed had a significantly higher ($P<0.05$) meat and bone %. Within the Pekin breed, ducklings fed food waste diets had significantly ($P<0.05$) higher skin and fat % than the ducklings fed the commercial control diet. Muscovy ducklings fed diets with food waste also had a higher skin and fat % than the control, but that difference was not statistically significant ($P>0.05$). Fatty acid profiles of the subcutaneous fat showed significant ($P<0.01$) breed differences. Most remarkable is the higher monounsaturated fatty acid content in the Pekin profile compared to that of the Muscovy which contained a significantly ($P<0.01$) higher percentage of polyunsaturated fatty acids. Muscovies had significantly ($P<0.01$) higher palmitic, linoleic and linolenic acids, while Pekins were significantly ($P<0.01$) higher in oleic acid (C18:1). Pekins had less than 1 % of each of C20:0, C20:3, and C20:4 fatty acids, but these were not detected in the Muscovy

profile. These results provide a clear proof of the possibility of utilizing food waste as an alternative source of ingredients for the formulation of feed for ducks.

INTRODUCTION

Meat type duck production is slowly increasing compared to the rapid productivity witnessed in the other poultry species, mainly chicken, during the last few decades. Production cost and low consumer preference for duck meat are the major reasons for this slow increase. As human diets are being blamed for various health disorders, consumers are demanding meat products low in fat and high in protein. Research is faced with the changing demand of consumers and hence is concentrating on the manipulation of the factors that influence carcass composition to render it comparable to, and as acceptable as, the other poultry species.

Abdelsamie and Farrell (1985) crossed Pekin and Muscovy and produced a mule duck with a carcass lower in fat and increased breast muscle thickness. Selection for leanness using the body size criterion has negatively affected reproductive traits and had not reduced the proportion of carcass fat (Scott and Dean, 1991). However, genetic selection of ducks through the use of a needle probe for measurements of breast muscle thickness increased breast muscle and decreased skin fat thickness (Pingel and Heimpold, 1983).

Muscovy duck production and consumption increased in France following the genetic improvement and consumer promotion program it underwent in the early 1970's. This breed exhibits a large sexual dimorphism where the Muscovy male is 35 % larger than the female (Stevens and Sauveur, 1985). Muscovy females were marketed in whole carcass form as each is enough for a family of four while the Muscovy drake was marketed in cut-up parts which, besides the higher meat content compared to the Pekin, helped increasing consumption and popularity of this breed.

Dietary factors as well have implication on carcass composition. Siregar et al (1982a,b) reduced the fat content of 14 and 56 day-old ducklings by decreasing the energy to protein ratio. Feed restriction (Campbell et al, 1985) and increasing dietary fibre (Siregar et al, 1982c) have also been reported to reduce fat in the carcass of ducklings.

Pekin and Muscovy ducks originated and have been domesticated in different environments and show different carcass fat contents. These two breeds also have different growth rates and hence their market age differs by 4 to 5 weeks. The environmental habitat and the marketing age might have an effect on the carcass characteristics. In ducks, as in the other poultry species, fatty acid composition is manipulated by the dietary fat source (Abdelsamie and Farrell, 1985).

Reports on feeding diets based on food waste to ducks are absent from the literature, however, some researchers have included various percentages of different kinds of wastes in the diets for chickens. El Bouchy (1994) fed 50 % food waste to laying hens without affecting their egg production or quality. Zia-Ur-Rehman et al (1994) reported feeding laying hens diets partially containing dried fruits and vegetables with results comparable to the control. Squires et al (1992) fed 20 % tomato pomace in broiler diets and reported no effect of the antinutritional factors present in the untreated tomato cannery waste on production parameters.

This study was performed to compare carcass yield and carcass composition of White Pekin and White Muscovy male ducklings, at their relative market age, fed nutritionally balanced experimental diets based on the chemical analysis of industrial food wastes.

MATERIALS AND METHODS

Three hundred Pekin and 300 Muscovy male ducklings were raised to market age on experimental diets based on industrial food wastes. Three treatments were offered to the birds, commercial pellets (control), a feed including partial waste, and a feed based on 100 % food waste. The nutritional composition of the 3 experimental diets is presented in Table 1.4. The average feed consumption for the 3 treatments per drake by breed is shown in Table 1.6.

From the growth trial, 4 representative birds per breed of duck per experimental treatment were randomly selected, one from each replicate pen, for carcass analysis. A total of 12 eviscerated and dressed carcasses from each breed was recovered from the processing plant[15] to determine their carcass yield and carcass composition. The Pekin and Muscovy birds were processed at 49 and 77 days of age, respectively, following the standard procedure adopted by the plant. The carcasses recovered were frozen empty shells plus necks and giblets (heart, liver, and gizzard). The carcass yield was determined relative to the live body weight of the birds before they were sent to processing. Frozen

[15]Brome Lake Ducks Ltd., Knowlton, Quebec, Canada. (Pekin ducklings)
Couvoir Simetin, St-Canut, Quebec, Canada. (Muscovy ducklings)

carcasses were longitudinally cut into two halves along the back bone using a butcher's band saw[16] and one of the halves was subjected to analysis. The half carcass was thawed and dissected using a surgical scalpel but the neck and the giblets were excluded from the analysis. The dissection fractionated the carcass into four components : skin plus subcutaneous fat, lean meat, bone, and intermuscular fat. Each fraction was then expressed as a percentage of the total eviscerated carcass weight.

The fatty acid composition of the subcutaneous fat of both Pekin and Muscovy breeds was analyzed by the gas-liquid chromatography[17]. Two replicates of fat tissues were sampled from a mixture of different subcutaneous fat pieces from each carcass .

Statistical Analysis :

Statistical analysis of the results was performed using the GLM procedure of the SAS (1991) library. The model included the effects of the diet, animal breed, and interactions. The dependent variables were carcass yield, carcass composition parameters, and fatty acid profiles. Each pen (replicate) represented an experimental unit. The design was factorial with 2 breeds, 3 treatments, and 4 replicates per treatment per breed. The three treatments were compared and contrasted using Sheffe's multicomparison test since we had 3 treatments with 2 degrees of freedom allowing for only two comparisons with a simple T-test. The mean square used to calculate the critical difference for Sheffe's test was the mean square error given by GLM since the treatment and breed effects were

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[16]Butcher Boy Model, Lasar MFG Company Inc., Los Angeles, CA, USA.

[17]Hewlett Packard Series II # 5890, Hewlett-Packard Company, USA.

considered fixed and hence the GLM procedure was appropriate.

The statistical model for the experiment is as follows:

$Y_{ijk} = \mu + \text{Treatment}_i + \text{Breed}_j + \text{Interaction}_{ij} + e_{ijk}$

Y_{ijk} = The measure of carcass yield, carcass composition parameters and fatty acid profiles of the k^{th} observation in the j^{th} breed receiving the i^{th} treatment.

μ = The overall mean

Treatment_i = The effect of the i^{th} treatment where $i=1$, 2, or 3.

Breed_j = The effect of the j^{th} breed where $j=1$ or 2.

Interaction_{ij} = The interaction of the i^{th} treatment and the j^{th} breed.

e_{ijk} = The error term associated with the k^{th} observation in the j^{th} breed receiving the i^{th} treatment.

Table 1.3 . Proximate analysis[a] of the waste ingredients used in the experimental diets on DM basis

Waste ingredients	DM	FAT	C.P.	ADF	Ash	Ca	P	G.E.
	%	%	%	%	%	%	%	kcal/kg
Peanut	95.61	52.70	28.58	13.1	2.72	0.25	0.64	6,634
Bread	89.31	3.65	15.79	1.01	1.88	0.02	0.17	4,387
Granola	88.36	9.60	6.51	0.79	1.31	0.06	0.14	4,811
Peanut skins	87.80	9.21	18.88	34.10	2.25	0.19	0.20	4,864
Cookies	84.92	3.49	11.47	0.00	1.34	0.11	0.25	4,249
Pogo meat	58.83	49.65	28.03	0.79	7.01	0.39	0.47	4,870
Pogo	56.04	22.95	19.95	0.78	5.18	0.29	0.26	5,068
Noodles	44.90	4.45	15.47	0.34	0.32	0.02	0.11	4,521
Tofu	35.64	27.21	61.58	1.21	3.96	0.29	0.89	6,267
Brewers grains	30.14	5.92	19.43	21.20	4.22	0.33	0.55	4,193
Canned food	29.31	2.28	22.83	8.23	7.57	0.11	0.29	4,058
Okara	23.29	12.73	32.89	15.71	3.84	0.28	0.50	5,468

[a] Proximate analysis was conducted at the Crampton Nutrition laboratory, Macdonald Campus of McGill University

Table 1.4. Nutritional composition of the 3 dietary treatments on dry matter (DM) basis

Nutrient	Commercial pellets			Partial waste			100% waste	
	Starter	Grower	Finisher	Starter	Gro-Fini	Wet	Dry	Wet
DM %	86.74	86.11	87.08	84.07	82.21	54.12	83.67	55.04
C.P.%	25.49	23.34	21.33	23.37	22.82	17.30	18.04	20.69
Fat %	4.07	3.72	5.54	10.01	14.52	8.84	7.53	9.14
ADF %	4.28	4.64	5.03	3.73	3.61	3.03	4.33	2.78
Ash %	6.12	5.48	5.33	6.32	5.77	5.49	5.95	5.63
Ca %	1.05	0.99	0.90	1.10	1.02	0.73	1.14	0.60
P %	0.73	0.81	0.73	0.80	0.70	0.82	0.68	0.64
GE kcal/kg	4,545	4,562	4,998	5,143	4,814	5,249	4,651	5,235

Proximate analysis was conducted at the Crampton Nutrition laboratory, Macdonald Campus of McGill University

Table 1.6. Average feed consumption on DM basis per duck by breed at appropriate market age

Breed	Commercial (kg)			Partial Waste(Percent) (kg)			100%Waste(Percent)[1] (kg)	
	Starter	Grower	Finisher	Starter	Grow-Finish	Wet	Dry	Wet
Pekin	0.703	1.977	4.842	0.244(3.4)	1.156(16.12)	5.769(80.5)	0.760(11.2)	6.045(88.8)
Total		7.522±0.11[a]			7.169±0.10[a]		6.805±0.10[a]	
Muscovy	1.956	4.160	5.841	0.648(5.6)	3.292(28.7)	7.547(65.7)	2.413(20.7)	9.260(79.3)
Total		11.957±0.27[a]			11.487±0.20[a]		11.673±0.25[a]	

Differences were not significant ($P>0.05$)

[1] The numbers in parenthesis represent the percent consumption of each ration and form of the diet

RESULTS AND DISCUSSION

Poultry diets including those for ducks are formulated using the metabolizable energy (ME) values of feedstuffs. However, there are no ME values available for industrial food wastes. Hence, formulation using food wastes involved estimation of the waste ingredient ME values. Total consumption of the major nutrients in the diets (Table 1.6) indicates that the birds fed the commercial pellets consumed more dry matter and crude protein than the birds fed the experimental treatments. However, those fed on the food waste diets consumed more fat.

Feeding food waste in a balanced diet did not affect the live body weight or the carcass yield presented in Table 2.1. There was no significant ($P>0.05$) interaction between the dietary treatment and the breed. Hence, it was reasonable to test for the treatments and breeds effects on the carcass yield. The statistical analysis of the yield has shown no effect of the dietary treatments. There was a significant ($P<0.05$) effect of breed on the yield where the Pekin had a higher dressing percent than the Muscovy breed for the ducklings fed either the control, the partial waste, or the 100 % food waste diet (Table 2.1). However, Pekin and Muscovy carcass yields were not significantly ($P>0.05$) different for the ducklings fed the control or the partial waste diet. Leclercq and de Carville (1985) reported higher carcass yield of the Muscovy males (62.6 %) at 12 wk of age when compared to Pekin males (60.3 %) at 8 wk of age. These results disagree with the results presented in this paper. However, the authors reported data collected at a time the Muscovy ducks had undergone a program of genetic selection

(Stevens and Sauveur, 1985). Moreover, these researchers show data indicating that the live body weight of the Pekin male was 2.388 kg at 8 wk of age. This reveals that this breed has also been the subject of genetic selection during the last decade for two reasons: the present live body weight for the Pekin male is about 1 kg more than reported, and this heavier weight is reached at 7 rather than 8 wk of age.

The effects of the dietary treatments and the breeds on the carcass composition of Pekin and Muscovy males at 49 and 77 d of age, respectively, are presented in Table 2.2. There was no significant ($P>0.05$) interaction between treatments and breeds for any of the carcass composition parameters. The treatments had no significant ($P>0.05$) effects on skin %, meat %, and fat %, but they had an effect ($P<0.05$) on bone % and skin plus fat %. The breed effect was significant ($P<0.05$) for all the composition parameters (Table 2.2). The Pekin breed exhibited higher skin and fat % than the Muscovy breed which possessed higher meat and bone %. These results agree with those reported by Leclercq and de Carville (1985) for Pekin and Muscovy males at 8 and 12 wk of age, respectively. Muscovy males had about 17 % (relative %) more meat and 13 % (relative %) less skin and fat than the Pekin males. These characteristics are behind its increasing popularity in Europe and North America where consumers are becoming more concerned about the effects of dietary fat intake on their health status.

The effect of feed composition and consumption on the carcass skin and fat was observed on both breeds, but was only significant ($P<0.05$) for the Pekin. This could be explained by the possibility that carcass fat content of Pekin is due to their rapid growth during the starting period characterized by rapid deposition of fat (Campbell et al, 1985). Another possible reason is that the Muscovy birds consumed approximately 11 % less wet feed and 46 % more dry feed, of the diet formulated of 100 % food waste, than the Pekin birds on the same treatment (Table 1.6). On the diet including partial food waste, Muscovies consumed 18 % less wet feed and 40 % more dry feed than the Pekin. Table 1.4 shows the gross energy (E) values of these feeds where the wet 100 % food waste had 11 % more energy on D.M. basis than the dry pellets of the same treatment. For the partial food waste diet, the E value of the wet mash on D.M. basis is only 8 % less than the grower-finisher pellets, but the birds on this treatment consumed less wet feed than the birds on the 100 % food waste treatment (Table 1.6).

The primary aim of the performance and carcass analysis studies was to determine the nutritional value of the industrial food waste in terms of replacing conventional feedstuffs such as corn and soybean that can be consumed by humans. The energy to protein ratio was not adjusted appropriately to produce a duckling as lean on food waste as on the control diet. More emphasis was put on supplying the birds with enough protein to explore the feasibility of utilizing food waste without impairing the birds' growth performance and carcass characteristics.

The effects of dietary treatments and breeds on the fatty acid profiles of subcutaneous fat of both breeds are presented in Table 2.3. There was no significant effect of treatments on the individual fatty acids except for palmitoleic acid (C16:1) and stearic acid (C18:0). The control diet had a significantly ($P<0.01$) higher percentage of palmitoleic acid than the other treatment by breed combinations. Stearic acid percent was significantly ($P<0.01$) less in the subcutaneous fat of the control birds than in that of the birds fed diets with food waste for the Muscovy breed. However, there was no significant ($P>0.05$) effect of treatments on the stearic acid content for the Pekin carcasses. Pekins had significantly ($P<0.01$) less stearic acid than Muscovies. The main differences in the fatty acid profiles between Pekin and Muscovy were the significantly ($P<0.01$) higher % of oleic acid in the Pekin and the significantly ($P<0.01$) higher % of palmitic and linoleic acids in the Muscovy subcutaneous fat. Other differences were the lack of C20:0, C20:3, and C20:4 in the Muscovy profile while the Pekin profile contained less than 1 % of these fatty acids. Muscovy carcasses possessed significantly ($P<0.01$) more ω-3 fatty acid (C18:3) than Pekins. Table 2.4 shows a comparison of the subcutaneous fatty acid profiles of Pekin and Muscovy with those of chicken adipose tissue, turkey skin fat, and beef tallow. The Pekin profile is closely comparable to that of the chicken and turkey. The Muscovy profile is very distinctive because it contains a saturated fatty acid % similar to tallow, but has the highest % in polyunsaturated fatty acids compared to the other species.

Although these two breeds were raised at the Macdonald Poultry Complex and received similar feed, the differences between their fatty acid profiles can be associated with many factors including body size and the feed. The differences in profiles between breeds might also be due to their different growth rates, processing ages and origins. More research is necessary to determine the differences between these breeds in terms of their lipid metabolism and modification of the dietary fatty acids.

Manipulation of fatty acid composition in ducks has been reported to occur through dietary regimens. Feeding sunflower oil increased the polyunsaturated fatty acid content of duck carcass fat (Abdelsamie and Farrell, 1985). Our results imply that the fat source in the food wastes used in the diets did not result in changes to the fatty acid profiles among the three treatments.

CONCLUSION

The results obtained from the carcass analysis demonstrate that industrial food wastes represent a valuable resource capable of replacing conventional feedstuffs, such as corn and soybean, in duckling diets. Diets formulated with food waste had no effects on the carcass yield or fatty acid profile of the subcutaneous fat. The high fat content of the experimental diets resulted in a high calorie:protein ratio and hence in higher fat deposition mainly subcutaneously. This was a secondary concern for our research since that ratio can be manipulated in order to produce leaner carcasses. The efficient utilization of food waste by the ducks will make it possible to transform what man reject into a good quality , and possibly more affordable, source of protein and energy for human consumption.

Table 2.1 . The effect of dietary treatments on live body weight, carcass weight, and carcass yield of Pekin and Muscovy ducklings at their respective market ages[1]

Treatment	Live Body Weight (kg)	Carcass Weight (kg)	Carcass Yield[2] (%)
Commercial			
Pekin	3.597	2.575	71.62[ab]
Muscovy	4.837	3.432	70.95[b]
Partial Waste			
Pekin	3.735	2.673	71.51[ab]
Muscovy	4.774	3.319	70.93[b]
100% Waste			
Pekin	4.079	3.001	73.564[a]
Muscovy	5.097	3.455	70.94[b]
SEM	0.12	0.06	0.73

[1] Pekin = 7 weeks; Muscovy = 11 weeks

[2] Carcass yield includes the neck and the giblets

[a,b] Means within columns with no common superscript differ significantly ($P<0.05$)

Table 2.2 . The effect of dietary treatments and breeds on carcass composition of Pekin and Muscovy ducklings at their respective market ages[1]

Treatment	Carcass weight (kg)	Skin[2] (%)	Meat (%)	Bone (%)	Fat[3] (%)	Skin+Fat (%)
Commercial						
Pekin	2.575	30.34[ab]	39.66[b]	23.91[a]	6.09[a]	36.43[b]
Muscovy	3.432	24.68[b]	48.23[a]	25.82[a]	1.26[b]	25.94[c]
Partial Waste						
Pekin	2.673	35.27[a]	39.81[b]	18.02[b]	6.89[a]	42.17[a]
Muscovy	3.319	25.91[b]	48.92[a]	22.67[a]	2.49[b]	28.40[c]
100% Waste						
Pekin	3.001	35.88[a]	39.52[b]	18.26[b]	6.34[a]	42.22[a]
Muscovy	3.455	25.86[b]	47.08[a]	24.56[a]	2.50[b]	28.36[c]
Mean						
Pekin	2.750	33.83	39.66	20.06	6.44	40.27
Muscovy	3.402	25.48	48.08	24.35	2.08	27.57
SEM	0.06	2.05	1.58	1.52	0.69	2.15

[1] Pekin = 7 weeks; Muscovy = 11 weeks
[2] Includes skin and subcutaneous fat
[3] Visceral and intermuscular fat
[a,b,c] Means within columns with no common superscript differ significantly ($P<0.05$)

Table 2.3 . Effects of treatments and breeds on the subcutaneous fatty acid profiles of Pekin and Muscovy males at market weight

	TREATMENT						
	Control		Partial Waste		100 % Waste		
FA (%)	PEKIN	MUSCOVY	PEKIN	MUSCOVY	PEKIN	MUSCOVY	SEM
C14:0	1.04^{b}	2.57^{a}	1.07^{b}	2.79^{a}	1.49^{b}	2.51^{a}	0.24
C14:1	0.11^{a}	0.14^{a}	0.15^{a}	0.12^{a}	0.14^{a}	0.06^{a}	0.02
C16:0	22.14^{b}	36.80^{a}	21.70^{b}	36.80^{a}	20.05^{b}	36.76^{a}	1.07
C16:1	3.28^{b}	5.29^{a}	3.58^{b}	3.67^{b}	3.03^{b}	3.59^{b}	0.42
C18:0	7.27^{c}	13.74^{b}	6.64^{c}	15.84^{a}	8.02^{c}	16.62^{a}	0.52
C18:1	47.82^{a}	4.08^{b}	48.34^{a}	4.23^{b}	46.38^{a}	4.52^{b}	1.36
C18:2	15.95^{b}	34.25^{a}	16.02^{b}	33.34^{a}	18.07^{b}	32.78^{a}	0.92
C18:3	1.19^{b}	2.16^{a}	1.30^{b}	2.14^{a}	1.73^{ab}	2.13^{a}	0.09
C20:0	0.14^{a}	-	0.11^{a}	-	0.13^{a}	-	0.01
C20:1	0.58^{b}	1.00^{a}	0.55^{b}	1.08^{a}	0.53^{b}	1.03^{a}	0.03
C20:3	0.13^{a}	-	0.16^{a}	-	0.13^{a}	-	0.03
C20:4	0.12^{a}	-	0.12^{a}	-	0.14^{a}	-	0.02

$^{a, b, c}$ Means within rows with no common superscripts differ significantly ($P<0.01$)

Table 2.4 . Comparison of subcutaneous fatty acid profile of Pekin and Muscovy with chicken, turkey, and beef tallow

Fatty Acid (%)	Pekin	Muscovy	Chicken[a]	Turkey[b]	Tallow[c]
Saturated	31.63	54.81	25.40	31.01	54
Monounsaturated	51.79	9.61	52.60	48.25	43.5
Polyunsaturated	17.41	35.60	22.00	19.83	2.5

[a] Leclercq and Whitehead, 1988. (adipose tissue)

[b] Ajuyah et al., 1993. (subcutaneous fat)

[c] Leeson and Summers, 1991. (beef tallow)

SECTION III

Digestibilities, energy, and nitrogen retentions of corn, soybean meal, and nine industrial food waste ingredients

Formulation of the experimental diets was based on estimations of the metabolizable energy of the food waste ingredients. Consequently, the birds on these diets consumed more fat and hence exhibited more fat deposition than the control. Tested rather than estimated enegy and digestibility values of these ingredients enable appropriate manipulation of a balanced diet. The objective of this study was to determine AME, AMEn, TME, TMEn, N retention, DM digestibility, fat digestibility, and NDF digestibility of corn, soybean meal, and 9 potential industrial food waste ingredients in a comparative study between Pekin and Muscovy ducklings at different ages of their growing periods.

The original idea to initiate this study was provided by Dr.E.R.Chavez and Dr.S.P.Touchburn. The research was financially supported by the Conseil des recherches en pêche et en agro-alimentaire du Québec.

ABSTRACT

Digestibility and energy values of corn, soybean meal, and food waste ingredients in a comparative study in Pekin and Muscovy ducklings at different ages

In addition to corn and soybean meal, a total of nine industrial food waste ingredients were tested in a comparative metabolic study in Pekin and Muscovy ducklings each one at 2 different ages of growth. The "precise-feeding" technique was performed to establish DM, fat, and fibre digestibility as well as N retention, AME, AMEn, TME, TMEn values for the 11 feedstuff ingredients. Peanuts had significantly ($P<0.05$) the highest energy value followed by pogo, granola, tofu, the food waste diet, bread, corn, soybean meal, brewers grain, okara, and peanut skins with 5195, 4195, 4019, 3967, 3498, 3220, 3216, 2357, 1829, 1712, and 1244 kcal AMEn/kg, respectively. Overall N balance was only negative for peanut skins. N retention was always significantly ($P<0.05$) higher with the ingredients rich in protein such as soybean meal, tofu, okara, pogo, peanuts and the food waste diet. N retention was low for bread, brewers grains, corn, and granola. DM digestibility was high for granola, pogo, corn, bread, and the food waste diet. Fat digestibility was in general the same for all the ingredients and was always over 97 %. NDF digestibility reflected the capacity of ducklings to digest the hemicellulose component with which NDF digestibility was associated. Bread NDF was significantly ($P<0.05$) the most digestible (88.92 % NDF digestibility) as it contained 96.29 % hemicellulose while okara NDF, besides peanut skins and soybean meal, was significantly ($P<0.05$) the least digestible (26.94 % NDF digestibility) as it contained 14.38 % hemicellulose. The results of this study establish reliable data for feed formulation of

duck diets using the tested industrial food waste ingredients as well as corn and soybean meal in both Pekin and Muscovy ducklings at 2 different growing ages.

INTRODUCTION

Reference tables for energy values of feedstuffs utilized in feed formulation for poultry are expressed as metabolizable energy (ME). For the most part, these tables contain values for conventional feed ingredients. Moreover, the ME values of these feedstuffs have been determined in chickens and are usually extrapolated to formulate diets for ducks. Apparent ME (AME, AMEn) and true ME (TME, TMEn) values in ducks for different conventional feedstuffs were reported in the literature by very few researchers. Furthermore, the evidence on the similarities of N and energy metabolism between ducks and chickens is controversial.

Our growth performance and carcass analysis studies have clearly established the industrial food waste ingredients as valuable resources that can be recycled either by specialized companies or without further processing, at least in local extensive animal production systems. During these studies, the ME values of food waste ingredients for diet formulation had to be estimated because of the absence of such a data base. The goal of those studies was to assess the feasibility of utilizing industrial food wastes as alternative sources of feedstuffs in ducks diets. The energy to protein ratio in the food waste diets was not appropriate enough to result in a non-significant difference between the control carcass composition and that of the carcasses produced on food wastes. However, visual detection of the higher fat content in the experimental carcasses was not possible and indicates that the manipulation of the E:P ratio will be sufficient to correct for the differences between treatments. Furthermore, future formulation with food wastes, whether for research or local animal production, has to be based on reliable values of the ME of the food waste ingredients. The objective of this study was to determine AME, AMEn, TME, TMEn, N retention, DM digestibility, fat digestibility, and NDF digestibility of corn, soybean meal, and 9 potential industrial food waste ingredients in a comparative study between Pekin and Muscovy ducklings at different ages of their growing periods.

MATERIALS AND METHODS

Sixty Pekin and 60 Muscovy day-old male ducklings were purchased from local commercial hatcheries[18]. The ducklings were housed in floor pens as described in section I, and fed commercial pellets during the non-experimental periods. At the age of 3 and 6 wk for Pekin and 7 and 11 wk for Muscovy, respectively, birds were randomly moved from floor pens to individual metabolic cages with 38, 50, and 50 cm of width, length, and height, respectively. Each bird served as an experimental unit with 5 birds per waste ingredient to be tested. Once in the cages, they continued to be fed commercial pellets ad libitum for 2 days of adaptation.

All the birds were fasted for 24 hr to ensure that their alimentary canals were empty of feed residues (Sibbald,1979). They were then fed a protein-free diet (Table 3.1) ad libitum for 5 hr and fasted another 24 hr during which the excreta voided by each bird was collected and frozen. Each bird served as its own negative control to estimate this

[18]Brome Lake Ducks Ltd., Knowlton, Quebec, Canada. (Pekins)
Couvoir Simetin, St-Canut, Quebec, Canada. (Muscovies)

metabolic and endogenous excretion. The birds were maintained under continuous light to avoid delay in voiding excreta such as may occur during periods of darkness (Sibbald and Morse,1982a). They were then precisely-fed the appropriate amount of a test ingredient, based on the capacity of the ducklings to accommodate feed in the enlargement of their oesophagus to avoid any impaction (Sibbald and Morse,1982b). This capacity was determined by a preliminary assay using the different waste ingredients that were high in fibre and had relatively lower densities than the others. In case of impaction of the enlargement of the oesophagus, the collection period of excreta was planned to be adjusted to 48 hr instead of 24 hr to ensure complete collection. Otherwise an overestimation of the true metabolizable energy (TME) would result. Once fed, the birds were individually weighed and housed in the clean wire-floored metabolic cages over excreta collection trays measuring 45, 55, and 5 cm of width, length, and height, respectively, and their housing times were recorded. Rigid plastic panels approximately 15 cm high lined the lower portion of each cage wire mash fence. Placed at a slight slope, they served to minimize cross-contamination of the fecal collection. Water was only offered 2 hr after the feeding to avoid regurgitation which was the main reason for eliminating observations. The excreta was collected on a quantitative basis in plastic trays . The diets and excreta samples were frozen, freeze-dried using a Virtis freeze-dryer[19], allowed to come to equilibrium with the atmospheric moisture, weighed, and ground through a 0.5 mm sieve. The ground samples were assayed for gross energy in an

[19]Virtis freeze dryer # 278341, Gardiner, New York, USA.

adiabatic oxygen bomb calorimeter[20]. The data were used to calculate AME, AMEn, TME, and TMEn values of the test material.

AME and TME are calculated according to the following formulas:

AME = IE - (FE + UE)

TME = AME + (FmE + UeE)

Where,

IE : is the ingested energy.

FE + UE : is the energy voided by the fed bird.

FmE + UeE : is the energy voided by the unfed bird.

AMEn and TMEn are the values corrected to zero nitrogen balance and are calculated as follows:

AMEn = AME - (8.22 * ANR ÷ FI)

TMEn = TME - (8.22 * FNL ÷ FI)

Where,

8.22 : is the energy in Kcal/g of nitrogen retained in the body or voided as products of tissue catabolism

ANR : is the apparent nitrogen retention (g) calculated as the difference between nitrogen intake and nitrogen output.

FNL : Fasting nitrogen loss

$TME = IE - (FE + UE) + (F_mE + U_eE)$

where IE : Ingested energy.

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[20]Number 1241, Pan Instrument Company, Moline Illinois, USA.

FE+UE : Energy voided by the fed bird.

$F_mE + U_eE$: Energy voided by the unfed bird.

Samples were then analyzed for dry matter (DM), nitrogen (N), neutral detergent fibre (NDF), acid detergent fibre (ADF), and total lipids to determine dry matter digestibility, N retention, fibre and fat digestibility. Chromium was used as a dietary marker, but the parameters were calculated using the total collection method.

The selection of food waste ingredients to be tested was based on their availability in large supply, their quality in terms of protein and energy as potential alternatives for conventional feedstuffs, their proximate analysis, and the least processing requirements. It was also based on the preliminary studies using a variety of these ingredients that pointed to their potential and indicated the usefulness of further nutritional evaluation in order to achieve optimum performance.

Thus, a total of 11 test ingredients were selected to assess their nutritive values in these comparative metabolic studies between Pekin and Muscovy ducklings. They included corn and soybean meal as reference conventional feedstuffs and 9 industrial food waste ingredients from the Greater Montreal region. The food waste ingredients were :

Okara : Okara is the by-product of soybean processed for tofu (vegetarian meat or cheese) production. It is commonly called okara fibre because of its high fibre content. The physical appearance resembles a white dough cake. During and after processing, quantities of **Tofu** are also discarded, mainly for being in a shape unsuitable for marketing. Both okara and tofu are good sources of protein.

Granola bars : They are products aimed for human consumption. Their waste results from decoding in its component mixture that cause variations in taste, making them unsuitable for sale. They are made of nuts, sugar, chocolate, and cereals and are rich in energy.

Bread : Bread waste that is either misshapen or stale. Stale bread was recollected as refusal of supermarkets. It is comparable to corn in dry matter and energy content, and has a higher protein content.

Brewers grains : These are the by-product of the brewing industry.

Pogo : Pogos are products for human consumption. The pogo is a sausage on a stick enveloped in dough and deep fried. Its waste results from over or undercooking, or being misshapen. It is a good source of energy and protein.

Peanut and peanut skins : Old peanuts and the peanut skins that result during the processing of peanuts represent a good value of energy and protein.

Food waste diet : A sample of the diet formulated exclusively of food waste was used for assessment of its nutritive value as it represents the combined form of these waste ingredients.

The chemical analysis of these ingredients is shown in Table 3.2. The samples were freeze-dried using a Virtis freeze-drier, and the dry matter was obtained using a vacuum oven[21]. The samples were ground through a 0.5 mm screen[22], for the precise-feeding technique, and to powder before being subjected to chemical analysis. Gross

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[21]National Appliance Company

[22]Tecator grinder # 3260, cyclotec, 1093 sample mill, Sweden

energy was measured using an adiabatic oxygen bomb calorimeter[23]. Crude protein was measured using a nitrogen analyzer[24]. NDF and acid detergent fibre (ADF) were determined using the method developed by Van Soest and fat was ether extracted. The ash content was determined using a muffle furnace[25].

Precision feeding :

A stainless steel funnel with a 40 cm stem long, and an external diameter of 1.3 cm and an internal diameter of 1.1 cm was used in the precision feeding technique. A non-nutritional petroleum based grease was used to lubricate the tube before introduction into the birds. The tube was then inserted from the beak into the bottom of the oesophagus to facilitate introduction of the test sample. The quantities thus precision fed were: 20, 40, and 60 g for 3, 6 and 7, and 11 wk old ducklings, respectively. The feed was placed in the funnel in small quantities to avoid exerting pressure on the oesophagus enlargement while pushing the feed via the tube. The feed was then pushed using a stainless steel rod as a plunger to which 3.0 cm diameter spherical knob was attached as a handle. A plastic sleeve was rivetted to the rod to limit the plunger from projecting out of the tube more than 0.5 cm. These 0.5 cm were essential to make sure all the feed was delivered into the oesophagus and no residues were left in the tube.

The bird was held by one operator close to the abdomen while the second operator held the beak, inserted the tube, and held the funnel at the appropriate depth in

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[23]Number 1241, Parr Instrument Company, Moline, Illinois, USA.

[24]Leco FP-428, Leco Corporation, St-Joseph, MI, USA.

[25]Model F-A1730, Sybron Thermolyne Dubuque, Iwoa, USA.

the oesophagus. The thumb and the index fingers of the left hand were used to maintain the depth of the tube by exerting a counter force on the external cone wall of the funnel.

Statistical Analysis :

Statistical analysis of the results was performed using the GLM procedure of the SAS (1991) library. The model included the effects of the ingredient, the animal breed, the age of the bird, and interactions. The initial body weight of the birds was included as a covariate. The dependent variables were DM, fat, and NDF digestibility, N retention, AME, AMEn, TME, and TMEn. Each bird represented an experimental unit. The design was factorial with 11 ingredients, 2 breeds and 2 ages per breed. The multicomparison Duncan test was used to separate the differences between the means for statistical significance ($P < 0.05$).

The statistical model for the experiment was as follows :

$$Y_{ijkl} = \mu + I_i + B_j + A_k + I{*}B_{ij} + I{*}A_{ik} + B{*}A_{jk} + I{*}B{*}A_{ijk} + \beta wt_{ijkl} + e_{ijkl}$$

where

Y_{ijkl} = DM, fat, and NDF digestibility, N retention, AME, AMEn, TME, and TMEn measurement of the l^{th} bird at the k^{th} age in the j^{th} breed receiving the i^{th} feed ingredient.

μ = Effect of the overall mean.

I_i = Effect of the i^{th} feed ingredient where $i = 1$-11.

B_j = Effect of the j^{th} breed where $j = 1$, or 2.

A_k = Effect of the k^{th} age where $k = 1$-4.

Interactions = $I{*}B_{ij}$, $I{*}A_{ik}$, $B{*}A_{jk}$, $I{*}B{*}A_{ijk}$

β = The regression of Y_{ijkl} on the initial body weight.

wt_{ijkl} = The initial body weight of the l^{th} bird at the k^{th} age in the j^{th} breed receiving the i^{th} feed ingredient.

e_{ijkl} = The error term associated with the l^{th} bird at the k^{th} age in the j^{th} breed receiving the i^{th} feed ingredient.

Table 3.1 . composition of the protein-free diet

COMPOSITION	%
CORN STARCH	88.15
ALPHACEL	6
CORN OIL	3
Ca_2HPO_4	1.8
LIMESTONE	0.5
NaCl	0.2
VITAMINS & MINERALS[a]	0.1
Cr_2O_3	0.25

[a]Mineral premix to be added at 0.05 % of the diet provides per kg feed for ducks: Iron, 95 ppm (Ferrous sulfate, 36.8% Fe) $FeSO_4$ dry powder; Zinc, 60 ppm (Zinc oxide, 73 % Zn) ZnO; Copper, 8 ppm (Cupric carbonate, basic $CuCO_3$ 55% Cu); Manganese, 60 ppm (Manganese oxide MnO_2 55% Mn); Selenium, 0.2 ppm (Sodium selenite 45.6% Se), Na_2SeO_3; Iodine, 0.4 ppm (Potassium iodide KI 76.4 % I).
Vitamin premix to be added at 0.05 % of the diet provides per kg feed: vitamin A, 2,500 I.U.; vitamin D_3, 400 I.U.; vitamin E, 10 I.U.; vitamin K, 0.5 mg; biotin, 0.1 mg; folacin, 0.5 mg; niacin, 55.0 mg; pantothenic acid, 11.0 mg; riboflavin, 4.0 mg; thiamine, 2.0 mg; thiamine-HCl; pyridoxine, 2.5 mg; vitamin B_{12}, 0.01 mg; ethoxyquin or BHT or Santoquin, 100.0 mg.

Table 3.2 . Chemical analysis[a] of the food waste ingredients tested in the metabolic studies on DM basis

Waste ingredients	DM	FAT	Crude Protein	NDF	ADF	Hemi-cellulose[b]	Ash	G.E.
	%	%	%	%	%	%	%	kcal/kg
Peanut	95.61	52.70	28.58	13.1	-	-	2.72	6,634
Bread	89.31	3.65	15.79	25.6	0.95	96.29	1.88	4,387
Granola	88.36	9.60	6.51	2.55	0.70	72.55	1.31	4,811
Corn	88.27	4.20	9.98	10.7	-	-	1.71	3,853
Soybean meal	88.13	0.62	55.00	7.03	-	-	6.20	4,116
Peanut skins	87.80	9.21	18.88	34.10	-	-	2.25	4,864
Waste diet	85.17	9.21	17.33	11.90	2.98	74.96	5.77	4,370
Pogo	56.04	22.95	19.95	6.24	0.72	88.46	5.18	5,068
Tofu	35.64	27.21	61.58	1.64	1.05	35.98	3.96	6,267
Brewers grains	30.14	5.92	19.43	53.40	19.53	63.43	4.22	4,193
Okara	23.29	12.73	32.89	13.70	11.73	14.38	3.84	5,468

[a] Chemical analysis was conducted at the Crampton Nutrition laboratory, Macdonald Campus of McGill University

[b] Hemicellulose as percent of the NDF

Table 3.3a . N retention, AME, AMEn, and DM, Fat, NDF digestibility values of the tested ingredients for Pekin ducklings at 3 wk of age

Ingredient	% digestibility			N retention	AME	AMEn
	DM	Fat	NDF	(mg)	kcal/kg	
Granola	87.31[a]	98.96[ab]	-	-39[bc]	3892[c]	3908[b]
Pogo	82.74[ab]	99.43[ab]	-	368[ab]	4122[bc]	3971[b]
Corn	79.17[bc]	98.34[b]	40.09[c]	-72[c]	3111[d]	3141[c]
Bread	75.52[c]	-	88.15[a]	-63[bc]	3117[d]	3142[c]
Peanut	72.98[c]	99.38[ab]	64.75[b]	413[ab]	5311[a]	5141[a]
Tofu	57.69[d]	98.96[ab]	-	588[a]	4261[b]	4019[b]
Okara	53.56[d]	99.48[a]	9.26[e]	400[ab]	1736[f]	1572[e]
Soybean meal	46.69[e]	-	20.16[d]	473[ab]	2474[e]	2279[d]
Brewers grains	15.30[f]	-	16.53[de]	-301[c]	1271[g]	1442[e]
Waste diet	74.06[c]	97.16[c]	55.85[b]	172[b]	3257[d]	3186[c]
SEM	1.22	0.17	2.04	52.15	79.16	76.55

[a-g] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.3b . N retention, AME, AMEn, and DM, Fat, NDF digestibility values of the tested ingredients for Pekin ducklings at 6 wk of age

Ingredient	% digestibility			N retention	AME	AMEn
	DM	Fat	NDF	(mg)	kcal/kg	
Granola	90.04^{a}	99.53^{a}	-	7^{e}	4081^{c}	4079^{c}
Pogo	86.80^{a}	99.66^{a}	-	754^{c}	4482^{b}	4327^{b}
Corn	84.27^{ab}	99.21^{a}	49.22^{c}	137^{e}	3229^{e}	3201^{e}
Bread	83.85^{ab}	-	89.04^{a}	226^{e}	3348^{e}	3302^{e}
Tofu	75.77^{c}	99.39^{a}	-	1991^{a}	4663^{b}	4254^{bc}
Peanut	73.38^{c}	99.43^{a}	69.92^{b}	648^{cd}	5473^{a}	5340^{a}
Soybean meal	63.54^{d}	-	19.25^{d}	1778^{a}	2781^{f}	2416^{f}
Okara	62.79^{d}	99.39^{a}	24.60^{d}	1237^{b}	1816^{g}	1562^{g}
Waste diet	79.44^{bc}	99.40^{a}	56.85^{c}	464^{d}	3662^{d}	3567^{d}
SEM	1.22	0.17	2.04	52.15	79.16	76.55

$^{a-g}$ Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.4a . N retention, AME, AMEn, TME, TMEn and DM, Fat, NDF digestibility values of the tested ingredients for Muscovy ducklings at 7 wk of age

Ingredient	% digestibility			N ret.	AME	AMEn	TME	TMEn
	DM	Fat	NDF	(mg)	kcal/kg			
Granola	90.38^{a}	99.36^{a}	-	102^{d}	4070^{c}	4050^{c}	4078^{c}	4078^{c}
Pogo	86.57^{ab}	99.47^{a}	-	859^{c}	4486^{b}	4310^{b}	4497^{b}	4497^{b}
Corn	86.09^{ab}	99.17^{a}	52.50^{d}	185^{d}	3313^{d}	3275^{e}	3318^{e}	3317^{e}
Bread	82.87^{b}	-	90.99^{a}	224^{d}	3282^{d}	3231^{e}	3282^{e}	3282^{e}
Peanut	71.74^{c}	98.93^{b}	70.34^{b}	756^{c}	5352^{a}	5197^{a}	5362^{a}	5362^{a}
Brewers grains	71.40^{c}	-	72.99^{b}	321^{d}	3310^{d}	3239^{e}	3311^{e}	3311^{e}
Okara	66.58^{cd}	99.44^{a}	27.33^{e}	1205^{b}	2030^{f}	1775^{g}	2030^{g}	2030^{g}
Soybean meal	66.20^{cd}	-	35.19^{e}	1863^{a}	2885^{e}	2502^{f}	2885^{f}	2885^{f}
Tofu	64.31^{d}	97.14^{c}	-	1452^{b}	3891^{c}	3575^{d}	3892^{d}	3891^{d}
Peanut skin	54.56^{e}	99.42^{a}	49.64^{d}	-279^{e}	655^{g}	884^{h}	674^{h}	675^{h}
Waste diet	85.23^{ab}	99.55^{a}	63.06^{c}	639^{c}	3854^{c}	3723^{d}	3864^{d}	3864^{d}
SEM	1.22	0.17	2.04	52.15	79.16	76.55	112.92	112.93

$^{a-h}$ Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.4b . N retention, AME, AMEn, TME, TMEn and DM, Fat, NDF digestibility values of the tested ingredients for Muscovy ducklings at 11 wk of age

Ingredient	% digestibility			N ret.	AME	AMEn	TME	TMEn
	DM	Fat	NDF	(mg)	kcal/kg			
Granola	91.58^{a}	99.06^{ab}	-	213^{d}	4045^{b}	4016^{b}	4055^{b}	4054^{b}
Pogo	86.67^{ab}	99.01^{ab}	-	1336^{b}	4309^{b}	4126^{b}	4320^{b}	4320^{b}
Corn	86.03^{ab}	98.56^{b}	60.84^{c}	363^{c}	3291^{d}	3241^{d}	3303^{d}	3303^{d}
Bread	79.56^{cd}	-	87.15^{a}	546^{c}	3276^{d}	3201^{d}	3289^{d}	3289^{d}
Okara	74.14^{de}	99.13^{ab}	51.48^{d}	2298^{a}	2320^{e}	1995^{e}	2332^{e}	2332^{e}
Peanut	71.31^{e}	98.93^{b}	72.83^{b}	1059^{b}	5208^{a}	5064^{a}	5222^{a}	5222^{a}
Tofu	68.86^{e}	97.98^{b}	-	2544^{a}	4254^{b}	3905^{b}	4270^{b}	4269^{b}
Soybean meal	57.98^{f}	-	23.05^{e}	2345^{a}	2553^{e}	2231^{e}	2566^{e}	2566^{e}
Peanut skin	30.85^{g}	99.76^{a}	0.32^{f}	-768^{e}	1184^{f}	1604^{f}	1190^{f}	1189^{f}
Brewers grains	29.34^{g}	-	28.25^{e}	123^{d}	1426^{f}	1293^{g}	1443^{f}	1443^{f}
Waste diet	82.99^{bc}	99.38^{ab}	61.42^{c}	1040^{b}	3716^{c}	3574^{c}	3729^{c}	3729^{c}
SEM	1.22	0.17	2.04	52.15	79.16	76.55	112.92	112.93

$^{a\text{-}h}$ Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.5 . Mean[*] energy and digestibility values of the tested ingredients

Ingredient	% digestibility			N ret.	AME	AMEn	TME	TMEn
	DM	Fat	NDF	(mg)	kcal/kg			
Granola	89.87^{a}	99.26^{ab}	-	69^{ef}	4028^{c}	4019^{c}	4068^{c}	4068^{c}
Pogo	85.85^{b}	99.39^{ab}	-	854^{c}	4362^{b}	4195^{b}	4409^{b}	4409^{b}
Corn	83.94^{bc}	98.82^{bc}	59.22^{c}	155^{ef}	3238^{e}	3216^{e}	3311^{e}	3311^{e}
Bread	80.50^{c}	-	88.92^{a}	217^{e}	3255^{e}	3220^{e}	3285^{e}	3285^{e}
Peanut	72.37^{d}	99.05^{abc}	69.54^{b}	717^{cd}	5345^{a}	5795^{a}	5300^{a}	5300^{a}
Tofu	66.39^{e}	98.52^{c}	-	1487^{a}	4293^{b}	3967^{c}	4018^{c}	4018^{c}
Okara	63.75^{e}	99.37^{ab}	26.94^{f}	1231^{b}	1957^{g}	1712^{g}	2165^{g}	2165^{g}
Soybean meal	58.60^{f}	-	24.41^{f}	1615^{a}	2673^{f}	2357^{f}	2726^{f}	2726^{f}
Peanut skin	42.70^{g}	99.59^{a}	24.98^{f}	-524^{g}	920^{h}	1244^{h}	933^{h}	932^{h}
Brewers grains	35.18^{h}	-	35.53^{e}	31^{f}	1845^{g}	1829^{g}	2144^{g}	2144^{g}
Waste diet	80.22^{c}	98.81^{bc}	59.22^{c}	582^{d}	3607^{d}	3498^{d}	3789^{d}	3789^{d}
SEM	1.22	0.17	2.04	52.15	79.16	76.55	112.92	112.93

[*]Mean values of both breeds at both relative ages.

[a-h] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.6 . Body weight change of Pekin ducklings by feed ingredient and age

Ingredient	Wt and wt losses of Pekin at 3 wk of age (g)			Wt and wt losses of Pekin at 6 wk of age (g)		
	Initial bwt[a]	Final bwt[b]	wt change	Initial bwt	Final bwt	wt change
Bread	819	799	-20	2260	2240	-20
Brewers grain	846	800	-46	2336	2262	-74
Corn	651	629	-22	1766	1749	-17
Granola	685	671	-14	1854	1842	-12
Okara	810	763	-47	2386	2307	-79
Peanut	682	656	-26	1811	1793	-18
Pogo	670	666	-4	1949	1998	+49
Soybean	812	783	-29	2252	2219	-33
Tofu	844	817	-27	2338	2315	-23
Waste diet	661	640	-21	1796	1796	0

[a]The initial body weight was recorded immediately before precise-feeding, after the adaptation and protein-free diet periods
[b]The final body weight was recorded immediately after the excreta collection of the precise-feeding period

Table 3.7. Digestibility and energy values of the tested ingredients for both Pekin (P) and Muscovy (M) at all ages

Table 3.7a . corn

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	86.09[a]	99.17[a]	52.50[b]	185[ab]	3313[a]	3275[a]
M	11	86.03[a]	98.56[a]	60.84[a]	364[a]	3291[ab]	3241[a]
P	3	79.16[b]	98.34[a]	40.09[c]	-72[c]	3111[b]	3140[a]
P	6	84.27[a]	99.21[a]	49.22[b]	137[b]	3229[ab]	3200[a]
SEM		1.22	0.17	2.04	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.7b . Soybean meal

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	66.20[a]	97.31[b]	35.19[a]	1863[b]	2885[a]	2502[a]
M	11	57.98[b]	99.86[a]	23.05[b]	2345[a]	2552[bc]	2231[b]
P	3	46.69[c]	90.11[c]	20.16[b]	474[c]	2474[c]	2279[ab]
P	6	63.54[a]	91.01[c]	19.25[b]	1778[b]	2781[ab]	2416[ab]
SEM		1.22	0.17	2.04	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.7c . Bread

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	82.87[a]	-	90.99[a]	224[b]	3282[a]	3231[a]
M	11	79.56[ab]	-	87.15[a]	546[a]	3275[a]	3201[a]
P	3	75.52[b]	-	88.15[a]	-63[c]	3116[a]	3142[a]
P	6	83.85[a]	-	89.04[a]	226[b]	3348[a]	3302[a]
SEM		1.22	-	2.04	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.7d . Brewers grains

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	71.40[a]	-	72.99[a]	321[a]	3310[a]	3239[a]
M	11	29.34[b]	-	28.25[b]	123[b]	1425[b]	1293[b]
P	3	15.30[c]	-	16.53[b]	-302[c]	1271[b]	1442[b]
P	6	-	-	-	-	-	-
SEM		1.22	-	2.04	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.7e . Granola

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	90.38[a]	99.36[a]	-	102[a]	4070[a]	4050[a]
M	11	91.58[a]	99.06[a]	-	214[a]	4045[a]	4016[a]
P	3	87.31[a]	98.96[a]	-	-39[a]	3891[a]	3908[a]
P	6	90.04[a]	99.53[a]	-	7[a]	4080[a]	4079[a]
SEM		1.22	0.17	-	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.7f . Okara

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	66.58[b]	99.44[a]	27.33[b]	1204[b]	2030[b]	1775[ab]
M	11	74.14[a]	99.13[a]	51.48[a]	2298[a]	2320[a]	1995[a]
P	3	53.56[c]	99.48[a]	9.26[c]	399[c]	1736[c]	1572[b]
P	6	62.79[b]	99.39[a]	24.60[b]	1236[b]	1815[bc]	1562[b]
SEM		1.22	0.17	2.04	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.7g . Peanut

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	71.74[a]	98.93[a]	70.34[a]	756[b]	5352[a]	5197[ab]
M	11	71.31[a]	98.40[a]	72.83[a]	1060[a]	5208[a]	5064[b]
P	3	72.98[a]	99.38[a]	64.75[a]	413[c]	5311[a]	5141[ab]
P	6	73.38[a]	99.43[a]	69.92[a]	647[bc]	5473[a]	6340[a]
SEM		1.22	0.17	2.04	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.7h . Pogo

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	86.57[a]	99.47[a]	-	859[b]	4487[a]	4310[a]
M	11	86.67[a]	99.01[a]	-	1335[a]	4309[ab]	4126[ab]
P	3	82.74[a]	99.43[a]	-	368[c]	4122[b]	3971[b]
P	6	86.80	99.66[a]	-	754[b]	4482[a]	4327[a]
SEM		1.22	0.17	-	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P < 0.05$)

Table 3.7i . Peanut skins

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	54.56[a]	99.42[a]	49.64[a]	-279[a]	655[b]	884[b]
M	11	30.85[b]	99.76[a]	0.32[b]	-768[b]	1184[a]	1604[a]
SEM		1.22	0.17	-	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.7j . Tofu

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	64.31[bc]	97.14[c]	-	1452[c]	3891[c]	3575[c]
M	11	68.86[ab]	97.98[b]	-	2544[a]	4254[b]	3905[b]
P	3	57.69[c]	98.96[a]	-	588[d]	4261[b]	4019[a]
P	6	75.77[a]	99.39[a]	-	1991[b]	4663[a]	4253[a]
SEM		1.22	0.17	-	52.15	79.16	76.55

[a, b, c, d] Means within columns with no common superscript are significantly different (P<0.05)

Table 3.7k . Food waste diet

Breed	Age	DM dig. %	Fat dig. %	NDF dig. %	N ret. (mg)	AME kcal/kg	AMEn kcal/kg
M	7	85.23[a]	99.55[a]	63.06[a]	639[b]	3855[a]	3723[a]
M	11	82.99[a]	99.38[a]	61.42[a]	1040[a]	3716[a]	3574[a]
P	3	74.06[b]	97.16[b]	55.85[a]	172[c]	3256[b]	3186[b]
P	6	79.44[a]	99.40[a]	56.85[a]	464[b]	3662[a]	3576[a]
SEM		1.22	0.17	2.04	52.15	79.16	76.55

[a, b, c] Means within columns with no common superscript are significantly different ($P<0.05$)

Table 3.8 . AMEn value by ingredient, breed, and growing period

Ingredient	Muscovy		Pekin	
	Starter	Grower-Finisher	Starter	Grower-Finisher
		kcal/kg		
Corn	3200	3200	3200	3200
Soybean meal	2500	2200	2300	2400
Bread	3200	3200	3200	3200
Brewers grains	3200	-	1440	-
Granola	4000	4000	4000	4000
Okara	1800	2000	1600	1600
Peanut	5200	5050	5150	5350
Pogo	4300	4150	4000	4300
Peanut skins	880	1600	-	-
Tofu	3600	3900	4000	4250
Food waste diet	3700	3600	3200	3600

RESULTS AND DISCUSSION

Determining true metabolizable energy values of feedstuffs with ducks was not an easy procedure. Although the protein-free diet feeders were placed outside the metabolic cages, Pekin ducklings carried the feed in their beak and dropped it in the excreta collection trays. Only AME and AMEn were possible to assess for this breed. Muscovy ducklings did not consume any of the protein- free diet which resulted in a limited amount of fasting excreta available for analysis of endogenous losses. Therefore, precise-feeding of the protein-free diet during the negative control period would be most appropriate to adopt in the future.

Brewers grains and peanut skins were the only food waste ingredients that provoked regurgitation problems. The physical structure of the fibre in the brewers grains and the tannins in the peanut skins were the likely major causes of oesophageal irritations resulting in regurgitation. In subsequent trials, brewers grains and peanut skins were mixed with corn as a diluter at a ratio of 2:4 and 1:3, respectively. Even these proportions induced regurgitation in some ducklings. Water was offered only after two hours from feeding to avoid regurgitation. In the growth performance study, peanut skins were included at 2.5 to 7 % of the diet only and hence no signs of irritation were observed.

Of the 120 ducklings included in this metabolic study, no mortality nor any observable physical trauma to the birds happened during the precise-feeding technique.

Pekin ducklings at 3 wk of age (Table 3.3a) were in negative N balance when fed bread, brewers grains, corn and granola, while those fed okara, peanut, pogo, soybean meal, tofu and the food waste diet were in positive N balance. These values are reasonable because the latter ingredients are good sources of protein. AME and AMEn values show that peanut, tofu, pogo, and granola were significantly ($P<0.05$) superior to the other ingredients including corn and soybean meal which values were not significantly ($P>0.05$) different from those of bread and the food waste diet. Dry matter digestibility of granola and pogo were superior to the other ingredients (Table 3.3a). The percent digestibility of fat in the ingredients ranged between 97.2 and 99.5 %. That is possibly due to the differences in digestibility of short, long and branched fatty acids in poultry species as well as the digestibility of mono and polyunsaturated fatty acids. Percent NDF digestibility was significantly ($P<0.05$) higher for bread followed by peanut, the food waste diet and then corn and soybean meal. NDF in okara was significantly ($P<0.05$) the least digestible. This variability in NDF digestibility can be explained by the hemicellulose component in the NDF of these ingredients. For example, NDF (cellulose, hemicellulose, and lignin) in bread is 25.6 % and ADF is 0.95 % which means that the hemicellulose content of bread NDF is 96.29% and this explains the high NDF digestibility of bread. Okara, however, has 13.70 % NDF, 11.73 % ADF, and hence 14.38 % hemicellulose in its NDF which explains its low NDF digestibility.

At 6 wk of age, Pekin ducklings maintained a positive N balance even when fed the ingredients that are relatively low in protein, but this balance was significantly ($P<0.05$) lower than that of the birds fed ingredients high in protein such as tofu, okara, and soybean meal. So as the birds grew older, they mobilized less endogenous amino acids to meet their maintenance energy requirement. AME and AMEn followed the same trend as at 3 wk of age with peanut having significantly ($P<0.05$) the highest value followed by tofu, pogo, and then granola. Also at this age, the Pekin ducklings were able to digest more dry matter from granola, pogo, bread and corn than from the other ingredients. There was no significant ($P>0.05$) difference among ingredients for fat digestibility. NDF digestibility followed the same trend at 6 wk as at 3 wk of age with NDF in bread being significantly ($P<0.05$) the most digestible.

Muscovy ducklings at 7 and 11 wk of age had no different capacity in energy and nutrient digestibility. At both ages, birds were in positive N balance except for the birds fed peanut skins. Tofu, okara, and soybean meal were significantly ($P<0.05$) superior to the others in terms of N retention . Again for AME, AMEn, TME, and TMEn, peanut had significantly ($P<0.05$) the highest value followed by pogo, tofu, and granola. These results were expected because of the high protein and fat content of these ingredients. DM digestibilities of corn , granola, pogo, and the food waste diet were not significantly ($P>0.05$) different. Percentage of NDF digestibility reflects the hemicellulose content of the ingredients, where bread was significantly ($P<0.05$) higher in NDF digestibility, followed by brewers grain, peanut and the food waste diet. Okara which had the lowest % of hemicellulose (14.38% hemicellulose) exhibited the lowest NDF digestibility. These values confirm the capacity of ducks to digest hemicellulose efficiently. The only difference in trend of NDF digestibility between the Muscovy ducklings at 7 and 11 weeks is the remarkably lower values for brewers grain and peanut skin as the ducklings grew older. At 7 weeks of age, 73 % NDF digestibility is a reasonable value for brewers grain that contains 53.40 % NDF and 19.53 % ADF , and hence 63.43 % hemicellulose which explains this digestibility level. However, the dramatic decrease at 11 weeks of age is possibly due to variability among birds or to some other artifact of the procedure rather than a real decline with increasing age. Resolution of this apparent anomally requires further investigation.

In general, the mean energy and digestibility values of the tested ingredients (Table 3.5) show that the energy values for corn and soybean meal are closely comparable to those reported for ducks in the literature (Ostrowski-Meissner, 1984; Mohamed et al, 1984). The food waste values fluctuated higher and lower than corn and soybean meal with the waste diet values reasonably comparable to these conventional feedstuffs commonly used in poultry diets. Table 3.7 a-k detail the digestibility and energy values by ingredients, breeds, and ages. These subtables compare the efficiencies for each ingredient during the growing and finishing periods of each breed. For all the ingredients except brewers grains and peanut skins, Muscovy ducklings at 11 weeks of age were significantly ($P<0.05$) more efficient in retaining N from the feed ingredients than the other breed by age combinations. The AMEn values for corn (Table 3.7a) showed no significant difference ($P>0.05$) among breeds at all ages. Therefore, the average (3200 kcal/kg) of these values is the recommended estimatefor diet formulations for ducks (Table 3.8). Muscovy ducklings at 7 weeks of age and Pekin at 6 weeks of age were most efficient in utilizing energy from soybean meal (Table 3.7b). Their N balances and DM were not significantly ($P>0.05$) different but Muscovies digested NDF significantly ($P<0.05$) more efficiently. Bread (Table 3.7c) was most interesting in its high NDF digestibility due to its high hemicellulose component. This digestibility was not significantly ($P > 0.05$) different among birds of different breeds and ages. The same was true for AMEn values recommending approximately 3200 kcal/kg as energy to be used in diet formulation for ducks (Table 3.8). Note that this value is the same as that recommended for corn in this study . Brewers grain values for Pekin at 6 weeks of age were lost because of regurgitation (Table 3.7d). Remarkable variability is observed between young and older Muscovy birds in terms of NDF digestibility reflected in the AMEn value where, at 7 weeks of age, is relatively 60 % higher for both AMEn and NDF digestibility when compared to 11 weeks of age. However the 11-wk values are not credible and must await re-evaluation. AMEn values for granola (Table 3.7e) showed no significant ($P > 0.05$) difference among breeds and ages suggesting a fixed energy value for granola of 4000 kcal/kg (Table 3.8). The age effect is clearly implicated in the ability of birds to digest the NDF of okara fibre (Table 3.7f). In both breeds, older birds were significantly ($P < 0.05$) more efficient than the younger ones in digesting okara NDF which has low hemicellulose component (14.38 %). The age effect showed an interaction with different ingredients. This does not agree with the results reported by Siregar and Farrell (1980) where they showed in ducklings a decrease in metabolizability of the diet with increasing age but not in chickens. Peanut (Table 3.7g) had the highest AMEn values without significant ($P > 0.05$) difference among breeds and ages as well as for the digestibility parameters. The energy value for feed formulation would be about 5200 kcal/kg (Table 3.8). Birds precisely-fed pogo were mainly in positive energy balance compared to the birds on the other ingredients (Table 3.6). Only Pekin at 3 weeks of age had significantly ($P < 0.05$) lower AMEn values than the other combinations. Table 3.7i presents peanut skins value for Muscovy ducklings only. Similarly to brewers grain and contrary to okara, young ducklings significantly ($P < 0.05$) digested NDF in the peanut skins when compared to the older birds. This observation suggests that the differences in the proportional fibre components of the NDF (cellulose, hemicellulose, and lignin) might cause the age by ingredient interaction in term of NDF digestibility. Older birds utilized energy in tofu (Table 3.7g) more efficiently ($P < 0.05$) than the younger birds, with the Pekin breed favoured over the Muscovies. Digestibility and energy values of the food waste diet were in general lower for Pekin at 3 weeks of age. AMEn values ranged between 3186 kcal/kg (reasonable value for duck diet formulation) and 3723 kcal/kg, which is about 500 kcal/kg higher than the appropriate value for formulation. This explains the higher carcass fat observation in the experimental birds observed by the carcass analysis.

CONCLUSION

These results are promising lights on the way toward establishing tables of energy and digestibility values for alternative feedstuffs as an incentive for their utilization in feed formulation. As the data presented reveal, these ingredients exhibit at least similar nutritive values to those of conventional feedstuffs. The interrelationships between the age of the ducklings and their metabolic activities suggest that different values must be retained in ration formulation for certain feedstuffs according to growth periods of the ducks. Some of these results point out the importance of differentiating NDF and ADF digestibilities in order to explain the ability of ducks to digest fibre. As food wastes have been proven to be valuable and capable of replacing conventional feedstuffs in duck diets, it is no longer appropriate to qualify them as wastes. Hence the determination of their real nutritive values will ensure better utilization of these feedstuffs and help to formulate balanced diets in terms of energy to protein ratio to improve carcass quality.

GENERAL DISCUSSION

The growth performance experiment presented in Section I compared the response of the two most popular meat type ducks, Pekin and Muscovy, when fed industrial food waste. The growth of the ducklings within breeds showed no significant ($P<0.05$) difference among the dietary treatments which included a commercial control and feeds consisting partially or entirely of food waste. Numerically, the birds fed the diet formulated with partial food waste yielded higher body weights for Pekin ducklings and the diet formulated with 100 % food waste resulted in the heaviest Muscovy ducklings at market age. Feed consumption within breeds showed no significant ($P>0.05$) difference as well, but feed efficiency was significantly ($P<0.05$) better for the experimental treatments and for Pekin over Muscovy ducklings because of their longer growth period. The 100 % food waste diet had the lowest protein level and consisted of only one ration for the starting, growing, and finishing periods of growth which exploited the ability of the ducklings to increase their feed intake to meet their energy requirements, for compensatory growth, and to perform well on diets consisting entirely of food waste. Feed consumption of the major nutrients in the diets indicated that the ducks fed diets formulated with food waste consumed more fat than those fed the commercial control. That was due to the characterized nutritional composition of the food waste ingredients used in the formulation of the experimental diets. The aim of the growth performance study was to assess first the feasibility of feeding food waste diets without impairing the performance of the ducks, and second to compare the response of

Pekin and Muscovy ducklings to these diets. This experiment proved that ducklings perform normally on diets consisting of food waste, but raised some questions as to the quality of their carcasses.

Similarly to live body weight, feeding food waste did not affect the carcass yield of the experimental ducklings. Pekin ducklings had significantly ($P < 0.05$) higher carcass yield than Muscovy ducklings fed either the control, the partial food waste, or the 100 % food waste diet. These results were in disagreement with those reported by Leclercq and de Carville (1985) due, most probably, to the genetic selection program the Muscovy breed had undergone before 1985 (Stevens and Sauveur, 1985). Regarding carcass composition, the treatments had no significant ($P > 0.05$) effects on the percent of skin, meat, and fat, but they had an effect ($P < 0.05$) on bone and skin-plus-fat %. The Pekin carcasses exhibited significantly ($P < 0.05$) higher skin-plus-fat % than did the Muscovy carcasses which possessed significantly ($P < 0.05$) higher meat and bone %. These results agree with those reported by Leclercq and de Carville (1985). The effect of feed composition and consumption on the carcass skin and fat was only significant ($P < 0.05$) for the Pekin ducklings. This may be explained by their rapid growth during the starting period characterized by rapid deposition of fat (Campbell et al, 1985). Another possible reason was the differences, among the two breeds, in the consumption of wet and dry feeds which had different fat contents. Muscovy ducklings consumed less wet feed and more dry feed than did the Pekin ducklings. The differences between breeds in fat deposition made their fatty acid profile interesting to analyze. Most remarkable was the higher proportion of the monounsaturated oleic acid in the Pekin subcutaneous fat compared to the Muscovy profile which contained a significantly ($P<0.01$) higher proportion of linoleic, linolenic and total saturated fatty acids. The Pekin profile was closely comparable to those of the chicken and turkey. The Muscovy fat contained 54.81 % of saturated fatty acids which make it similar to the value for beef tallow. The differences between the fatty acid profiles of Pekin and Muscovy subcutaneous fat may be associated with their different growth rates, processing ages, and geographical origins.

During the growth performance study, the energy to protein ratio was not adjusted appropriately to produce ducklings on food waste as lean as those on the control diet. More emphasis was put on supplying the birds with enough protein to explore the feasibility of utilizing food waste without impairing the birds' growth performance and carcass characteristics. After these aims have been achieved, and the potential of feeding food waste had been established, it was essential to determine reliable nutritive values of these food waste ingredients as data base for feed formulation. Assessing DM, fat and NDF digestibility as well as AME, AMEn, TME, TMEn, and N retention of these feedstuffs revealed that several of them are at least as nutritive as corn and soybean meal. As formulated, the food waste diet was calculated to have 3200 kcal ME/kg. However, when assessed in the metabolic study, the energy value of this diet ranged between 3186 and 3723 kcal AMEn/kg reflecting the high fat content of certain ingredients which resulted in the high fat carcasses observed in the experimental birds during carcass analysis. The energy values established in this study will enable nutritionists to formulate balanced diets in which the energy to protein ratio will fall within values to produce lean ducks comparable to those of the commercial control. NDF digestibility of the various ingredients revealed the capacity of ducklings to digest the hemicellulose component and that there was an interaction between the NDF digestibility and the various ingredients. This observation should contribute to explaining the controversy over the capacity of ducks to digest fibre more efficiently than chickens. This digestibility varies with the ingredients and their proportions of NDF components.

GENERAL CONCLUSION

with the increase in human population, arable and permanent crops land is increasing and this is mainly at the expense of forest and woodland which is decreasing (FAO, 1995). However, grain land is expected to decrease by 17 %, irrigated land by 10 %, forest land by 20 %, and grazing land by 20 % per person between the year 1990 and 2000 (Brown, 1991). Land is no longer responding well to chemical fertilizers, hence boosting production is constrained and growth cannot be infinite. Current animal production systems are making farm animals compete with humans for grain and cereal consumption. According to the World Bank estimates, 630 million poor people are unable to provide themselves with a healthy diet, and 3.4 billion people depend on grain to get enough calories and protein. Although grain production is increasing, on a per capita basis it is decreasing and this is imposing more demand for alternative animal feeding systems to reduce the competition for grain and spare it for human consumption. Three experiments were performed in the present study to determine the nutritive values of industrial food wastes as alternative feedstuffs for duck meat production and their effect on carcass quality. These experiments have clearly proven the feasibility of feeding diets consisting exclusively of food wastes to growing ducks. The results demonstrated normal growth performance without adverse effects on carcass quality. The determination of the energy and digestibility values of these food waste ingredients established reliable data for formulating nutritionally balanced diets for ducks. This recycling of food wastes through animal production is an urgent necessity at the time when the impact of growing population and economic activities are rapidly depleting the natural resources. The urgent demand for sustainable agricultural systems does require a better utilization of the resource base. Production of primary resources depends on an ecologically acceptable and still economically profitable animal agriculture system. This system would contribute toward ensuring the availability of these resources for many generations to come.

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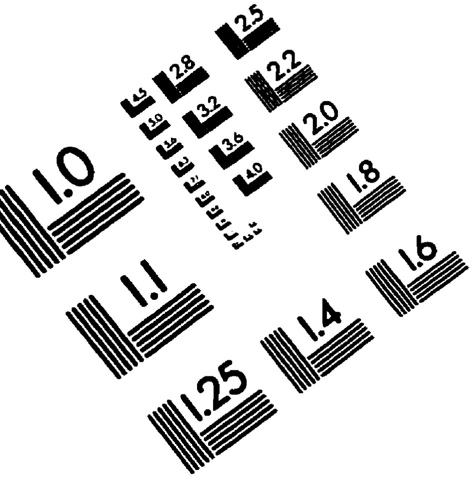
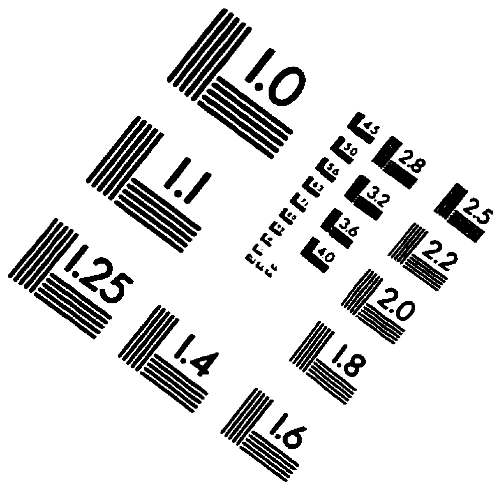
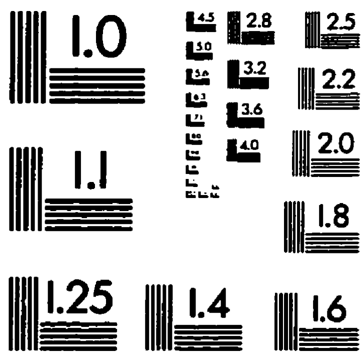
IMAGE EVALUATION TEST TARGET (QA-3)

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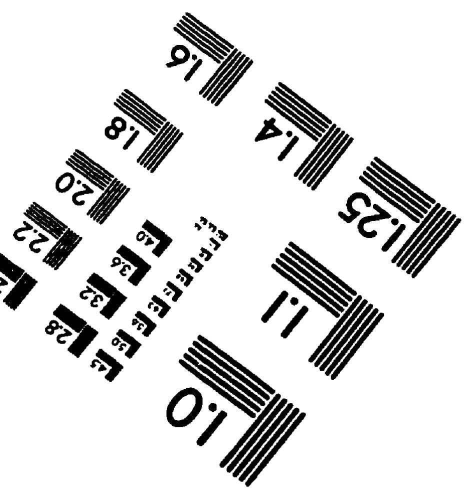
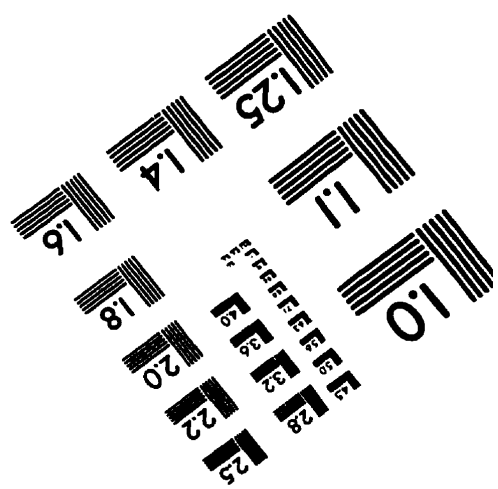

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