J. Food Sci. Nutr.
Vol. 6, No. 4, p. 257~262 (2001)

– Review –

Utilization of Poultry Processing Wastes

Linus G. Fonkwe, Rakesh K. Singh* and Jun Ho Lee†**

Department of Food Science, Purdue University, West Lafayette, IN 47907-1160, USA
**Department of Food Science and Technology, Univ. of Georgia, Athens, GA 30602-7610, USA*
***Division of Food, Biological and Chemical Engineering, Taegu University, Kyungpook 712-714, Korea*

Abstract

Large amounts of poultry processing wastes including blood, feathers, offal, bones and manure are produced annually from the poultry industry. Over the past years, these products have been wasted and now there is a need for the treatment of these processing wastes. These processing wastes could be either discarded, a rather expensive option considering the cost of sewage disposal, or processed into animal feed or food for human consumption. This paper mainly deals with the various methods through which the different poultry processing wastes have been further processed and/or utilized for human food or animal consumption. This paper also reviews steps involved in general poultry processing.

Key words: utilization, poultry, processing, wastes, review

INTRODUCTION

The poultry industry is a very important industry in the U.S. providing many jobs and a cheap source of animal protein. According to USDA (1) estimates, more than 1.42×10^7 tons of chicken and 2.51×10^6 tons of turkey were produced in the U.S. in 2001 while total poultry meat produced in Korea was 4.73×10^5 tons in 2000. This was matched by a per capita consumption of 41.3 and 8.2 kg for chicken and turkey meats, respectively.

Considering the large number of birds that are being processed, it is obvious that large quantities of poultry processing wastes are also being generated. For example, since feathers make up between 4 and 5% of the total body weight of a bird (2), at least 5.7×10^5 tons of chicken feathers and 1.0×10^5 tons of turkey feathers were produced in 2001. Similarly, a bird loses about 3% of its total body weight as blood during processing (2), which means that more than 5.0×10^5 tons of poultry blood was also produced in 2001. Large quantities of offal, bones and manure were also produced during the processing of poultry meat.

Thus, there is a need for the treatment of these processing wastes. These processing wastes could be either discarded, a rather expensive option considering the cost of sewage disposal, or processed into another animal feed or food for human consumption. This paper mainly deals with the various methods through which the different poultry processing wastes have been further processed and/or utilized for human food or animal consumption.

OVERVIEW OF POULTRY PROCESSING

In the poultry industry, the term processing refers to slaughtering, feather removal and evisceration. Prior to slaughtering, birds are placed in crates and/ or cages in the poultry farm, and transported in trucks and trailers to the poultry processing plant. Consideration is given to the size of the bird, and the temperature and humidity of the truck or trailer during loading and transportation of the birds. Care is also taken to minimize bruising the birds. Upon arrival at the processing plant, the birds are carefully weighed, removed from the crates or cages and hung upside down on kill lines where they are immobilized by electrical stunning or by carbon dioxide. The individual stages involved in the processing of poultry are summarized below.

Slaughtering

Birds are usually killed by cutting the carotid artery and the jugular vein found in the neck region. This method is preferred to decapitation, which may result in a reduced bleeding rate. The birds are then bled for between 90 and 180 seconds.

Scalding and picking

Scalding is the preparation of the removal of feathers (picking) after bleeding. It is usually done by immersing the birds in hot water with strict time-temperature control. The scalded birds then enter a chamber called the picker where rotating rubber fingers beat on the surface of the birds to release the feathers. Dry picking (without the preceding scalding step) is still practiced occasionally. Some feathers (pin feathers) need to be removed by hand after the birds leave the picker. While still in the line, the birds are washed with pressurized water and then transferred to the evisceration area.

†Corresponding author. E-mail: leejun@biho.taegu.ac.kr
Phone: 82-53-850-6535, Fax: 82-53-850-6539

Evisceration

The upper esophagus and crop of each of bird are removed and an incision is made through the abdominal wall under the tail of the bird. Through this opening, all the internal organs of the bird are removed. The heart, liver and gizzards are trimmed, cleaned and saved as giblets while the rest of the internal organs (intestines, spleen, lungs, reproductive organs, etc.) are discarded with the heads and feet as offal. The carcasses are then thoroughly washed and the feet are cut off.

Packaging

The carcasses are now chilled in cold water or in an ice-water mixture in tanks called chillers. The rate of chilling is properly controlled to avoid any chilling defects such as cold shortening. The chilled birds are then packaged whole, or cut into various parts and/or pieces prior to packaging. The slaughtered birds can then be packed in ice in wooden boxes, or in fiberboard and plastic bags with vacuuming. They can also be packed in trays with plastic overwrappings.

Deboning

The manufacture of comminuted meat products like sausages, hot dogs, ground meat patties, and so on, requires the use of boneless meat. Boneless meat can only be acquired by deboning the birds. The deboning can be done manually (by hand) or mechanically using deboners. Mechanical deboning is only carried out on frames, backs and necks. The mechanical deboning process has been adequately described by Newman (3). Basically, the meat and bones are ground in a blender and fed into a pressure chamber with a fine mesh screen. Alternatively, the meat and bones are crushed into small pieces and forced between a belt and a drum with grooves. Fine meat particles and fat pass through the screen or grooves while some meat particles, connective tissue and bonds do not and are collected as waste.

Some commercial deboners common in the poultry industry today, include the Beehive, Paoli and Baader deboners. There are other kinds of deboner that are operational today and can be found in patent literature. Another excellent source for the operation and different deboners is the article by Stadelman et al. (4).

MAJOR PROCESSING WASTES AND THEIR USES

Blood

Blood is the waste material resulting from the slaughtering and bleeding steps. Blood constitutes about $4\sim5\%$ of the total body weight of young birds of ages between 28 and 49 days old (2). Approximately 5.0×10^5 tons of bloods were produced in U.S. in year 2001 alone (assuming that a bird looses 3% of its body weight through the loss of blood during processing (2)). The blood can be converted into blood meal, or used as fish baits or fertilizer. During the preparation of blood meal, the blood must first be rendered. Water is evaporated from the blood in a cooker to low moisture content. The cake is pressed to lower its fat content to about 10%, and then ground to pass through an $8\sim12$ mesh screen. This material is then mixed with mineral supplements and spices to form blood meal. Alternatively, the blood could be mixed with offal and feathers, and then rendered to make a combined meal. The rendered blood meal is rich in proteins and mainly used for animal feed where they are a valuable source of proteins.

A waste-handling system (the "Dri-flo" system) has been developed by Norbest Turkey Growers' (Moroni, UT) to handle many poultry processing wastes, including water, blood, feathers and offal (5). The system consists of two main parts: the "no trough" system that takes care of the wastewater, and the K-system. The "no trough" system consists of two self-cleaning conveyor belts with flanking catwalks, suspended from the ceiling of the plant. The stainless steel belts travel towards one another from opposite ends of the room, conveying wastes into a central hopper. The wastes are transported to the K-System for further processing. The suspended lines also have stainless steel washbasins and faucets along the catwalls. Any overflow wastewater that spills onto the flow is recycled through diatomaceous earth and treated with chlorine compounds. The system is reported to have saved 400 gallons of water per minute in the plant.

Figure 1 shows the layout of the K-System. The K-System hydrolyzes and dries 249.5 kg of blood, 1,474.2 kg of feathers and 1,428.8 kg of offal per hour into a poultry meal. Feathers, offal and blood offal and blood are hydrolyzed in separate large tanks. The liquid feather hydrolysates are collected in surge tanks and pumped into blend tanks where they are combined with the offal and blood hydrolysates. The combined hydrolysates are then centrifuged, evaporated and dried to obtain fat, dicalcium phosphate and dried meal. Based on a 150-days operation (equal to 100 days at design rate), an operating profit of $140,110 was reported.

Even through poultry blood can potentially be rendered into blood, the availability of larger volumes of blood from beef and hog-processing plants has limited their use in the manufacture of blood meal.

Feathers

Feathers are the waste materials from the scalding and picking stages during the processing of poultry. They constitute about $4\sim5\%$ of the live body weight of the birds (2). Thus at least 5.7×10^5 tons of chicken feathers and 1.0×10^5 tons of turkey feathers were produced in the U.S. in 2001.

Characteristics of feathers vary by sex, species, age and the area of the body from which they are recovered. Thus feathers are classified into various categories. For example, "fancy feathers" must be removed prior to scalding, and include rooster neck hackles and tails. Feathers from turkey hips, necks, back, wing and tails are also classified as "fancy".

The majority of the feathers are recovered from the pickers. They are washed to remove blood and dirt, then dried and fluffed with air. Sometimes, the feathers may be bleach-

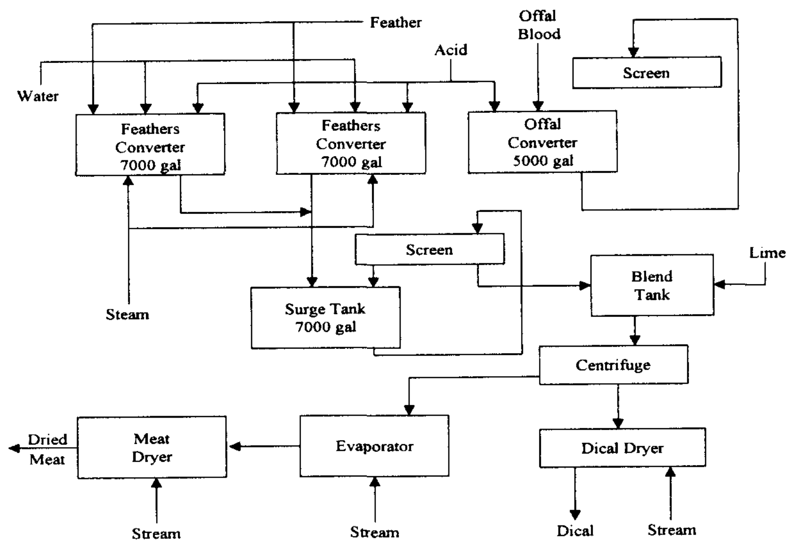

Fig. 1. Lay out of the K-system used to process poultry processing wastes into dried poultry offal (5).

ed prior to the washing step, or sprayed with mineral oil after drying. The dried feathers are then sorted by size using air and steam. The feathers are further sorted by source, color and cleanliness.

The feathers are used in a variety of ways: i) Body feathers are used for beddings, upholstery and sleeping bags; ii) Feathers from some bird species can be used for decorative purposes in ornaments, plume pens, toys, decorations, and so on; iii) Carefully selected feathers can be used for sporting equipment, such as for fishing lures; iv) Feathers decompose readily and mulch and can therefore be used as fertilizers; v) They can be used in the manufacture of fibers, as well cloth and paint brush.

Feathers can also be processed into a feather meal, or a combination of blood meal and feather meal, and used as an efficient protein source in animal feed. One procedure for the conversion of feather into feather meal is outlined in Fig. 2 (6). Basically, the feathers are collected, washed, dried,

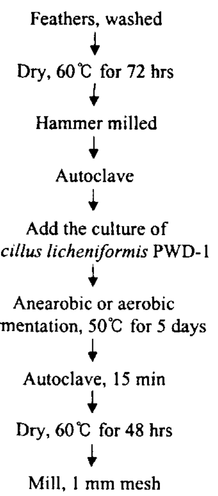

Fig. 2. Schematic protocol for the preparation of feather protein used in the diets of growing broiler chicks (6).

ground and then fermented aerobically or anaerobically. The feather-degrading bacteria (*Bacillus licheniformis* PWD-1) was first isolated and characterized by Williams et al. (7). Alternatively, the feathers may be steam hydrolyzed in a cooker. For example, Liu et al. (8) utilized 3.2 kg steam pressure/ cm^2 to hydrolyze feathers for 8 min in a cooker.

Goedeken et al. (9) reported that a blood meal diet (beef blood) and a blood with feather (55% : 45%) combined meal diet were more efficient sources for proteins in *in-situ* and digestion studies compared to soybean meal. The composition of the base meal is shown in Table 1. The feather/ blood meal was used as a replacement for the soybean meal in different proportions.

The blood meal and feather meal complimented each other with the blood meal supplying lysine while the feather meal supplied the sulphur amino acids (cystein and methionine). Liu et al. (8) in their nutritional evaluation of feather meal found that the total amino acid availability (TAAA) of the meals ranged from 62.1 (aspartic acid) to 82.4% (arginine), as shown in Table 2. The metabilizable energies of the meals ranged from 2,877 kcal/kg dry weight for a turkey/chicken feather meal to 3,122 kcal/kg dry weight for a chicken feather meal.

Waltz et al. (10) reported a low ruminal degradation of proteins of feather meal (32% compared with 53% for soybean meal), a low total tract digestibility (63.4%) and a high amino acid flow into the duodenum, as well as a high amino acid absorption in the duodenum and small intestines of diary cattle. Cabel et al. (11) described the use of feather meal in fat reduction in broilers.

Haque et al. (12) have described the extrusion processing of poultry processing wastes into animal (poultry) feed. They ground the waste (whole hens, offal, feather meal or ground feathers) and combined it with other ingredients to form a diet. The diet was then extruded at 132°C for 7 min, in batches of 90.7 kg.

Table 1. Protein values of feather meal for ruminants as affected by blood additions

Ingredients	% DM basis
Corncobs	70.51
Soybean meal	18.21
Molasses	10.00
Limestone	0.27
Bicalcium phosphate	0.75
Trace minerals[1)]	0.03
Vitamin premix[2)]	0.02

[1)]10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co.
[2)]15,000 IU vitamin A, 3000 IU vitamin D, 3.75 IU vitamin E per gram of premix.

Table 2. True amino acid availabilities (TAAA) (%) of feather meals

Nutrient	Turkey feather meal	Turkey/ chicken feather meal	Chicken feather meal	Mean
Aspartic acid	62.1	64.0	60.9	62.4
Threonine	70.4	71.6	73.7	71.9
Serine	75.7	80.1	83.8	79.9
Glutamic acid	71.8	69.5	72.7	71.3
Alanine	73.2	72.4	88.0	77.9
Cystine	64.2	64.6	63.9	64.2
Valine	77.2	76.8	77.1	77.0
Methionine	73.7	72.7	76.9	74.4
Isoleucine	80.3	80.1	82.4	81.0
Leucine	75.5	76.4	78.9	76.9
Tyrosine	74.5	78.8	75.9	76.4
Phenylalanine	76.6	78.9	82.0	79.2
Histidine	65.0	59.8	67.3	64.1
Lysine	60.5	51.0	65.8	59.2
Arginine	82.4	82.0	84.1	82.8

Offal

Offal is the internal organ of the birds plus the head and feet that had been cut off during and after evisceration. Generally, the offal are hydrolyzed in acid (13-15) and processed into animal feed. The procedure of Machin et al. (13) is summarized in Fig. 3.

Van Lunen et al. (15) fed an acid processed poultry hydrolysate to pigs in levels up to 15%. They reported that as the amount of acid-processed offal in the diet increased, there was a linear depression in the growth rate. A decrease in daily feed consumption was also reported. Even though there was such decrease in growth rate and daily feed consumption with increase in the ratio of acid-processed offal in the diet, the researchers concluded that it could be acceptable to use the acid-processed offal at levels up to 10% without any significant negative effects.

The inclusion of an offal meal in a barley-based diet has been shown to be beneficial in increasing the amount of polyunsaturated fats in pork. Van Lunen et al. (15) reported that inclusion of an acid-processed poultry offal hydroysate in the diets of feeder pigs at levels up to 15% led to an increase in total polyunsaturated fat in pork (after slaughter) and a decrease in total saturates. At the same time, they

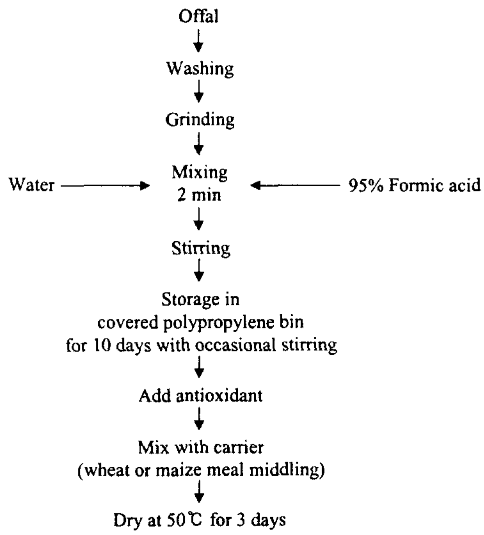

Fig. 3. Outline for the production of a dry meal containing poultry offal hydrolysate (13).

could not notice any significant effect on the flavor, tenderness, juiciness, free moisture and shear measurements on the pork.

Deboner residue

A major waste material coming from the poultry processing plant is the deboner residue. It is estimated that of the approximately 2,415,000 tons of turkey produced in the U.S. in 1991 (1). 169,000 tons of mechanically deboned turkey residue (MDTR) was produced (4). This amount of MDTR contains about 18～20% proteins (16-18). This amounts to about 32,000 tons of proteins, which can potentially be recovered and used for human consumption. However, the MDTR, like chicken deboner residue, is being sold at a cheap price and used for the manufacture of bone meal for animal feed (16).

Muscle (non collagenous) proteins have been extracted from deboner residue using various solvents. Young (19) used a solution of sodium malate and sodium chloride; Kijowski and Niewiarowicz (16) utilized 6% sodium chloride solution in their extraction, while McCurdy et al. (17) utilized an alkaline solution of sodium hydroxide in water (pH 10.5).

Fonkwe and Singh (18,20) have investigated some factors that affect the extraction of proteins from MDTR, including the concentration of sodium chloride in the extraction solvent, the ratio (vol/wt) of solvent to solids, the temperature and pH of extraction medium. They recommended 1% sodium chloride solution as an extraction solvent, with a solvent/solid (vol/wt) ratio of 4 : 1 to 5 : 1 at room temperature (20～22°C) and pH 10.5 to pH 10.7. The recommended duration of the extraction process was 25～35 min.

The extracted muscle proteins have been recovered from the water or salt solution in three main ways. One method that has been used is isoelectric precipitation where the pH of the protein solution is reduced to between 5.2～5.5, followed by centrifugation to recover the proteins (17). Young (19) precipitated proteins (extracted from a chicken deboner residue) from solution by lowering the ionic strength of the protein solution. Fonkwe and Singh (18) have done some isoelectric precipitation, as well as protein precipitation using the polysaccharides I-carrageenan and carboxymethyl cellulose. They also investigated the use of the polysaccharide chitosan for protein precipitation from solution. Figure 4 is an outline of protein recovery process from mechanically deboned turkey residue using a dilute alkaline sodium chloride solution for protein extraction and a dilute polysaccharide solution for protein precipitation.

Ozimek et al. (21) have investigated some of the functional and nutritional properties of the acid precipitated proteins. They reported that the nitrogen solubility (measure of protein solubility), emulsion capacity and heat gel strength of the acid precipitated proteins were lower than those of protein paste produced from deboned chicken meat. However, the acid precipitated proteins stabilized emulsions better than the protein paste from the deboned chicken. The nutritional evaluation of the acid precipitated proteins showed that the proteins were of high nutritional quality.

The use of proteins recovered from poultry deboner residue in sausages and luncheon meat has already been investigated (22,23). Kijowski et al. (22) reported using a protein extract, recovered from chicken deboner residue to replace water in a commercial sausage formulation. The sausage showed improved color, sensory characteristics, rheological properties and emulsion stability. Jelen et al. (23) reported that no significant differences in texture measurements (drip loss and sensory evaluation) were observed in

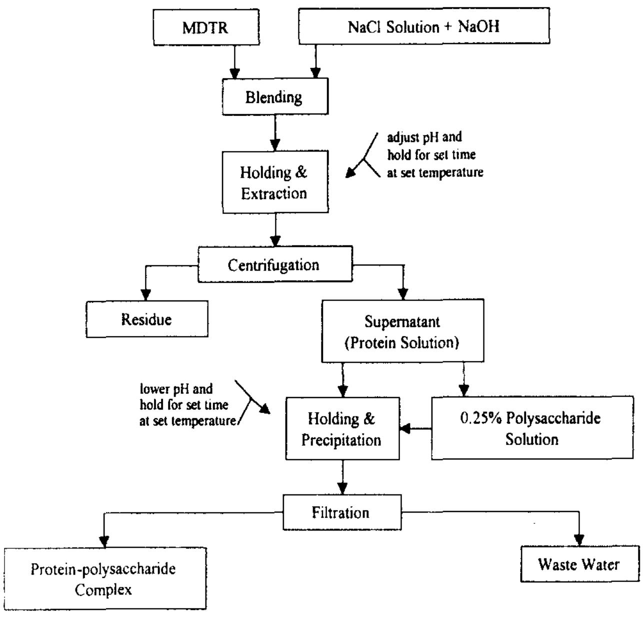

Fig. 4. Procedure for the recovery of proteins from mechanically deboned turkey residue using dilute alkaline sodium chloride solutions (18).

all-chicken luncheon meat when the poultry meat was replaced with alkali extracted/acid precipitated proteins from chicken bone residue at levels up to 20%. In fact, the report showed that only small differences were observed at replacement levels between 20% and 40%.

The main protein recovery processes that have led to a significant yield of proteins from MDTR have been by McCurdy et al. (17) and Fonkwe and Singh (24) of 12% and 11.7%, respectively. These processes have involved the use of high pH values (10 ~ 10.7) during protein extraction and low pH values during protein precipitation (pH 5 ~ 5.5). These large changes in pH could lead to a product with poor functional properties (even though the nutritional quality may be good), rendering the protein very unuseful during processing. Furthermore, processing of proteins under very high pH conditions could lead to the formation of potentially toxic amino acids like lysino-alanine (25) and lanthionine.

To avoid the use of extreme pH conditions during protein recovery from MDTR, the enzymatic recovery of MDTR muscle proteins can be used. Enzymatic hydrolysis of proteins has been shown to improve the functional properties of many proteins. Fonkwe (26) indicated that the enzymatic protein recovery process could produce a higher protein yield, with less technical demands than the other protein recovery processes we have used previously.

Poultry bones can also be used as a solid support for enzyme immobilization (27). Pepsin immobilized on a born matrix in a continuous reactor could clot 100 bed volumes of milk without loss of throughput or curd yield.

Manure

The most visible waste from poultry production and processing probably is manure. Poultry manure can be processed into either a meal that can be used as animal feed, a fertilizer for growing various crops, or digested for biogas production.

Shih (28) has reviewed the anaerobic thermophilic digestion of poultry manure to produce methane gas, liquid nutrients for aquaculture use and a solid residue for use as feed supplement. The process also kills pathogens in the manure at the same time. The manure can also be properly dried and held in an anaerobic environment for two to three weeks before use as a feed supplement. Alternatively, poultry manure can be fermented aerobically (29), or treated with heat (30) prior to use as an animal feed supplement.

The safety aspect of feeding bulls and pigs diets containing poultry manure (little) was investigated by Gilka et al. (31). They reported that although chemicals (antimicrobials and pesticides) were found in the organs of the animals fed the diet containing the poultry manure, the levels present were in concentrations well below the permitted limits. Ilian et al. (32) successfully used a sheep diet containing up to 40% poultry manure in the feeding of sheep without causing any significant changes in the sensory attributes of the mutton produced from the sheep. Similarly, others have also successfully used various levels of poultry manure in animal feed to obtain meat with excellent quality: cattle (33-35), fish (36), and sheep (32,37). Treated poultry manure has also been used successfully as fertilizers for growing sugar beet (38) and grape vines (39).

REFERENCES

1. USDA : Agricultural Statistics. U.S. Dept. of Agriculture, Washington D.C. (2001)
2. Salmon, R.E. : Slaughter losses and carcass composition of the medium white turkey. *Brit. Poultry Sci.*, **20**, 297 (1979)
3. Newman, P.B. : The mechanical recovery of meatA new look at the technology. In "*Upgrading Wastes for Feed and Food*" Ledward, D.A., Taylor, A.J. and Lawrie, R.A. (eds.), Butterworths, London, p.93 (1982)
4. Stadelman, W.J., Olson, V.M., Shemwell, G.A. and Pasch, S. : *Egg and poultry-meat processing*. Ellis and Herwood Ltd., Chichester, England, p.207 (1988)
5. Anonymous : Processing wastes for profit. *Food Eng.*, **43**, 56 (1971)
6. Williams, C.M., Lee, C.G. and Garlich, J.D. : Evaluation of a bacterial feather fermentation product, feather-lysate, as a feed protein. *Poultry Sci.*, **70**, 85 (1991)
7. Williams, C.M., Ritcher, C.S., Mackenzie, J.M. and Shih, J.C.H. : Isolation, identification and characterization of a feather-degrading bacterium. *Appl. Environ. Microbiol.*, **56**, 1509 (1990)
8. Liu, J.K., Waibel, P.E. and Noll, S.L. : Nutritional evaluation of blood meal and feather meal for turkeys. *Poultry Sci.*, **68**, 1513 (1989)
9. Goedeken, F.K., Klopfenstein, T.J. and Stock, R.A. : Protein value of feather meal for ruminants as affected by blood additions. *J. Animal Sci.*, **68**, 2936 (1990)
10. Waltz, D.M., Stern, M.D. and Illg, D.J. : Effect of ruminal protein degradation of blood meal and feather meal on the intestinal amino acid supply to lactating cows. *J. Dairy Sci.*, **72**, 1509 (1989)
11. Cabel, M.C., Goodwin, T.L. and Waldroup, P.W. : Feather meal as a nonspecific nitrogen source for abdominal fat reduction in broilers the finishing period. *Poultry Sci.*, **67**, 300 (1988)
12. Haque, A.K., M.A., Lyons, J.J. and Vandepopuliere, J.M. : Extrusion processing of broiler starter diets containing ground whole hens, poultry by-product meal, feather meal, or ground feathers. *Poultry Sci.*, **70**, 234 (1991)
13. Machin, D.H., Hector, D.A., Capper, B.S. and Carter, P.M. : The utilization by broiler chicken of poultry offal hydrolyzed in formic acid. *Anim. Feed Sci. Technol.*, **11**, 247 (1984)
14. Machin, D.H., Hetor, D.A., Swann, G. and Parr, W.H. : The use of formic acid prepared poultry offal hydrolyzate made from poultry slaughterhouse waste in diets of fattening pigs. *Trop. Sci.*, **25**, 41 (1985)
15. Van Lunen, T.A., Wilson, R.L. and Poste, L.M. : The effect of dietary poultry offal hydrolysate on the fatty acid composition and meat quality of pork. *Canadian J. Animal Sci.*, **70**, 1041 (1990)
16. Kijowski, J. and Niewiarowicz, A. : A method of protein extraction from chicken bone residue and chemical and electrophoretic characteristics of the extract. *J. Food Technol.*, **20**, 43 (1985)
17. McCurdy, S.M., Jelen, P., Fedec, P. and Wood, D.F. : Laboratory and pilot Scale recovery of proteins from mechanically separated chicken residue. *J. Food Sci.*, **51**, 742 (1986)
18. Fonkwe, L.G. and Singh, P.K. : Protein recovery from mechanically deboned turkey residue. *Trans. Am. Soc. Agric. Eng.*, **37**, 527 (1994)
19. Young, L.L. : Composition and properties of an animal protein isolate prepared from bone residue. *J. Food Sci.*, **41**, 606 (1979)
20. Fonkwe, L.G. and Singh, R.K. : Protein recovery from mechanically deboned turkey residue by enzymic hydrolysis. *Process Biochem.*, **31**, 605 (1996)
21. Ozimek, G., Jelen, P., Ozimek, L., Sauer, W. and McCurdy, S.M. : A comparison of mechanically separated and alkali extracted chicken protein for functional and nutritional properties. *J. Food Sci.*, **51**, 748 (1986)
22. Kijowski, J., Niewiarowicz, A., Laskowska, M. and Matuszak, H. : Use of protein extract from bone residue in poultry meat processing. *J. Food Technol.*, **20**, 51 (1985)
23. Jelen, P., Lawrence, R.A. and Cerrone, M. : Evaluation of alkali-extracted chicken protein for use in luncheon meats. *Can. Inst. J. Food Sci. Technol.*, **15**, 289 (1982)
24. Fonkwe, L.G. and Singh, R.K. : Extraction of salt and alkali-soluble proteins from mechanically deboned turkey residue-effect of some variables using response-surface methodology. *J. Food Process. Preserv.*, **18**, 47 (1994)
25. Lawrence, R.A. and Jelen, P. : Formation of lysino-alanine in alkaline extracts of chicken proteins. *J. Food Prot.*, **45**, 93 (1982)
26. Fonkwe, L.G. : Production and characterization of proteins from mechanically deboned turkey residue. *Ph.D. thesis*, Purdue University, West Lafayette, IN, USA (1996)
27. Findlay, C.J., Parkin, K.L. and Yada, R.Y. : Bone as a solid support for the immobilization of enzymes. *Biotechnol. Lett.*, **8**, 649 (1986)
28. Shih, J.C.H. : Recent development in poultry waste digestion and feather utilizationa review. *Poultry Sci.*, **72**, 1617 (1993)
29. Naber, E.C. : The refeeding of cage layer manure subjected to aerobic fermentation. ASAE Publi. No.13, **85**, 182 (1985)
30. Kirov, K.D. and Vitkov, M. : Study of some quality indices for meat from calves fed a diet containing heat treated manure litter. *Veterin. Nauki.*, **21**, 66 (1984)
31. Gilka, J., Gajduskova, V., Malikova, M., Masek, J., Docekalova, H., Hais, R., Lanikova, A. and Pavlasova, M. : Foreign substances in the meat and organs of bulls and pigs fed with domestic and food-industry wastes, including paste with poultry droppings. *Veterin. Med.*, **32**, 721 (1987)
32. Ilian, M.A., Razzaque, M.A. and Salman, A.J. : Unconventional feeds for sheep : effects on performance and meat quality and composition. *Biol. Wastes*, **24**, 115 (1988)
33. Yoo, M.I., Chung, C.Y. and Han, I.K. : Studies on the recycling of animal wastes. V. Studies on the nutritive values of dried poultry waste and dried pig manure in laying rations. *Korean J. Animal Sci.*, **19**, 380 (1977)
34. Ogumodede, B.K. and Aninge, A.J. : Utilization of dried poultry manure by growing chickens fed on a practical diet. *Brit. Poultry Sci.*, **19**, 137 (1978)
35. Petrovic, L., Petrovic, M., Ristic, M. and Lazor, M. : Carcass and meat quality of cattle fed poultry manure meal. *Technol. Mesa.*, **26**, 305 (1985)
36. Nandeesha, M.C., Keshavanath, P. and Udupa, K.S. : Evaluation of organoleptic qualities of fish grown in ponds treated with different organic manures. *Fish. Technol.*, **21**, 94 (1984)
37. Viscovan, A. Calatoiu, A. and Trandafir, T. : The potential for use of poultry manure as feed for sheep. *Revista de Cresterea Animal*, **29**, 25 (1979)
38. Bell, C.I., Jones, J., Milford, G.F.J. and Leigh, R.A. : The effects of crop nutrition on sugar beet quality. *Aspects of Appl. Bio.*, **32**, 19 (1993)
39. Bavaresco, L., Fraschini, P., Ubigli, M., Stefano, R.D. and Versini, P. : Long term studies on the application of granulated poultry manure as organic fertilizer to grape vines. Effect on the grapes and the wines. *Vignevini*, **18**, 59 (1991)

(Received August 9, 2001)