UTILIZATION OF POULTRY WET BY-PRODUCTS FOR ANIMAL FEED APPLICATIONS

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The utilization of offal from poultry slaughterhouses is a difficult problem from the standpoint of environmental safety and economics. Offal from chicken slaughterhouses (entrails, feathers, feet and heads) was ground, and extrusion cooked at 65–185 °C. The extruded product was supplemented into a standard broiler diet as a replacement of 6–8% animal meat and bone meal, used in control groups. In feeding experiments, the performance of experimental birds was slightly better than that of controls, as the body weight increase was 1.91 kg in the experimental group, compared with 1.76 kg in the control group after seven weeks of feeding experiment (the standard deviation 0.053), and significantly different feed conversion ratios were obtained (1.91 and 1.85 kg/kg, respectively, the standard deviation of 0.032). No significant differences were observed concerning health and mortality. The material, considered as highly risky, was thus found as safe after extrusion, and suitable from economic and environmental reasons.

chicken feed; poultry offal; excrusion cooking

INTRODUCTION

Intensive animal production, while being quite efficient, has left behind huge quantities of by-products. Every day, the offal from processing plants is produced in tremendous amounts, which creates serious economic and environmental problems.

An option for utilization of these waste products is to convert them, through extrusion cooking, into useful feed ingredients, which could be used as a protein source in a final formulation. Another option is to convert them, again through extrusion cooking, into a complete feed. This latter alternative can be accomplished by blending by-product materials with an otherwise complete feed formulation to extrude a final product, meeting total physiological needs of the farm animal. Either option employs the extrusion cooking as the means of imparting energy, both mechanical and thermal, into the finished product.

The extrusion cooking, as the name implies, is a continuous cooking process, which yields a pasteurized, expanded or unexpanded product, which is then subjected to a relatively short drying process. The final product yields a value-added feed or feed ingredient that is shelf stable and free of pathogenic microorganisms. There is almost no limitation to the type of processing wastes and by-products, which can be used in this manner.

Nowadays, the extrusion cooking of food and feed is a common method in the respective industrial sectors. There exist several advantages of this technology:

- Improved digestibility and feed efficiency as protein degradation is reduced in the short-time high-temperature process.
- Extrusion temperature is high enough to eliminate some residual pesticides, which may have contaminated the feed.
- Extrusion conditions reduce natural toxin levels.
- Unlike traditional rendering, the extrusion produces feed free of *Salmonellae* and other pathogenic organisms, analogous as in pasteurised products.
- The extrusion requires less energy per ton, when compared to traditional rendering.
- Lower initial investment is needed than in dry rendering facilities.

To utilize raw and wet processing wastes and by-products from slaughterhouse, two processing steps must be used (Rokey, 1994).

- Grinding in a meat grinder to reduce particle size with uniform distribution, and to reduce bones and other hard particles to a smaller size. Dry ingredients as vegetable raw materials, should be also reduced in particle size as it promotes a uniform moisture uptake by all particles.
- Prior to extrusion cooking, ingredients are mixed together in defined proportions, and the mixture is processed in the preconditioner with steam addition.

The two factors limiting the addition of by-products and/or wastes are the moisture and fat contributed by the addition of by-products and wastes. The moisture content of these products usually ranges between 60–87%, and is the primary limiting factor. When complete feed is extruded, the finished pellet must be durable for transport and handling. A general rule of thumb is to add as much processing waste or by-product to the extruder during processing so that the added moisture does not exceed 22–25%. If non-durable pellets may be produced, the amount of by-product, which could be added, substantially increases. The influences on uniform temperature height throughout the extrudate rise, while retaining complete pasteurization. A typical level is then 50% by-product and 50% carrier material (i.e. defatted soy meal or cereals).

Most by-product formulations are extrusion-cooked at moisture contents over 30%. A portion of this moisture is lost due to flash evaporation at the extruder die and the expansion of the extruded material. Further moisture is lost during evaporative cooling. Drying this material under ambient conditions is also possible, but it is very slow, requiring large spaces, and the possibility of recontamination is thus increased. The main reason for reducing the moisture level after extrusion is to increase the shelf stability. Moreover, a pathogenic-free environment is retained at drying air temperatures of 94–150 °C. Following drying, the product temperature should be reduced to 30–40 °C prior to storage or packaging (Rokey, 1994).

The goal of extrusion cooking of by-products is to utilize them economically, and to use them as value-added substance. A typical chemical composition of an extrudate obtained from a mixture of 50% fresh poultry viscera and 50% soybean meal (Wenger, 1995) is as follows: 48.05% protein, 5.26% crude fibre, 7.11% ash, 83.90% total digestible nutrients, 8.86% crude fat hydrolysis products, and 5.68% moisture.

The extrusion cooking of a complete feed or extrusion-cooked feed components for further processing offers many advantages. Adding such by-products directly to complete diet eliminates the need for extra processing of the material later on. Nevertheless, it should be remembered that there are two categories of animal by-products:

- high risk materials (viscera, mortality);
- low risk offal, such as feathers, clean carcasses, heads, feet, and bones.

According to EU regulations (White Book..., 2000), high-risk products have to be sterilized for at least 20 min at 130 °C at least. However, the extrusion cooking by itself gives an opportunity of sterilization during material processing (preconditioning, extrusion, and drying), even when the total required time might be too short for such materials, comparing with that regulations.

Due to experimental results (Wenger, 1995; Ben Gera, 1996), the risk of any infection is very limited during properly prepared baro-thermal processing, like extrusion. This result was proved by scientists of the North Carolina State University during broilers fed ration containing extrusion-cooked ground dead poultry. The body weights and feed conversion factors of broilers were similar or even better than those observed with birds fed unprocessed mash feed (Wenger, 1995; Ben Gera, 1996).

Another, and rather a difficult problem is the utilization of feathers. Economists say that it is too costly, nutritionists say that it is questionable in respect to feeding value. Feathers as a by-product are produced in huge amount, creating serious environmental and ecological problems. Raw feather meal proteins contain disulphide bonds, which are resistant to digestion. Heating the feather meal to 180 °C for 40 min, which is the most common method used in the industry at present, will break down these bonds partially, increasing the digestibility to about 60%. Sometimes, an acid hydrolysis is employed as an additional step to rise the digestibility up to 70–80% levels, but this additional step is expensive.

Adding enzymes can be helpful, however, some preliminary processing is needed. Simple addition of enzymes to feather meal without any pretreatment to open up the feather protein structure is not effective (Wenger, 1995; Ben Gera, 1996). Sometimes, an addition of a strong reducing agent can be added to protein material, but this operation must be still accompanied by a severe process method to make the feather meal protein more susceptible to enzymatic attack. Proteases with a very high keratinase activity are very expensive and dangerous. They would digest skin, hair, feathers and other components, but are considered a very potent health hazard. These enzymes are also inactivated by heating to the extrusion temperature. Claims to add an enzyme to feather meal prior to extrusion see little or no benefit of the enzyme addition. Nevertheless, research in this field continues, and safe enzymes combined with proper incubation times before the extrusion cooking may soon become feasible.

We are convinced that the extrusion-cooking technique gives a unique engineering and economic opportunity to solve the problem of feathers utilization.

Inspired by the above mentioned American research results (Wenger, 1995), we carried out experiments to better understanding the utility of extrusion cooking of animal wet by-products. We wanted to determine, how much the inclusion of processed poultry offal in broiler diets would influence body weights, feed conversion, health and/or mortality of birds.

MATERIAL AND METHODS

Poultry offal, consisting approximately of 40% feathers, 30% entrails and 30% feet and heads, collected as fresh material from a slaughter house, was carefully ground to the particle size of about 0.5 mm, than mixed with other feed ingredients, and the mixture was precooked in a cylindrical preconditioner, where wet steam at the temperature of 130 °C was introduced. The conditioning time was about 2 min, the final moisture content of preheated material about 30%. The by-product was added in a proportion required by the experimental procedure.

The extruder was a twin-screw counter-rotating conical type model 2S-9/5, produced by ZMCH Metalchem, Gliwice, Poland. Main process conditions were as follows: temperature range from 65 °C (Section I of the barrel) through 185 °C (Section III of the barrel) till 130 °C at the die (4 mm); screw rotation speed – 2 Hz (120 rpm), average capacity about 205 kg/h.

Extrudates were dried in a belt drier (at temperature 120 °C for 30 min) to the moisture content of 6%, than crumbled. Crumblings obtained in this way were used as a complete feed ration for broiler diet. The feed composition is given in Table I. The poultry offal substituted commercial industrial animal meal (Table I). The animal meal consisted of utilized overall meat industry wastes, not detailed by the producer (ZU Miroslawiec, Poland) as they are rather variable according to supply of raw material; similarly, their composition is not specified in detail in most imported products. Its total protein content was 55%. The composition of control unprocessed feed and the experimental feed containing extruded offal instead of animal meal are shown in Table I. The content of selected nutrients in the latter diet is shown in Table II.

The following methods were used for the determination of nutrients (all of them, Polish official standard methods); protein using Kjeldahl method (PN-75/A-04018), fat using the Soxhlet procedure (PN-76/R-64753), lysine (PN-74/R-64815) and available methionine (PN-77/R-64821) using the Amino Acid Analyzer, tryptophan colorimetrically (PN-77/R-64820), phosphates using a titration method of quinolino-molybdate (PN-90/C-04528), calcium

I. Composition of control unprocessed mush and extrusion cooked feed

Raw materials	Starter (%)	Grower (%)	Finisher (%)
Corn	58.00	65.00	72.00
Soybean meal	26.00	19.00	15.00
Animal meal*	8.00	8.00	6.00
Calcium diphosphate	0.70	0.80	–
Limestone	0.80	0.80	0.50
Animal fat	3.50	2.00	–
Salt (NaCl)	0.50	0.25	0.30
Choline	0.20	0.20	0.20
Methionine	0.20	–	–
Trace minerals	0.20	0.20	0.10

* In mush, in extrusion feed: the same amount of extruded chicken offal

II. Content of some nutrients in chicken diets with poultry offal

Nutrient	Starter (%)	Grower (%)	Finisher (%)
Crude protein	24.00	21.50	18.70
Fat	6.20	5.90	5.00
Lysine	1.29	1.05	0.91
Methionine	0.60	0.40	0.35
Tryptophan	0.34	0.28	0.23
Phosphate	0.69	0.70	0.57
Calcium	0.96	0.95	0.92
Sodium	0.16	0.19	0.21

and sodium contents using atomic absorption spectrophotometer. Cysteine was not determined as it is no essential amino acid, but its content could be interesting for the evaluation of final nutritional value. The cysteine content is rather high because of the presence of feathers, so that it could contribute to the nutritional value of methionine.

Feeding trials were conducted with 150 Astra B broiler chickens (females) fed *ad libitum* either control feed or a ration containing extrusion ingredients. Each group consisted of 3 replicates, each containing 25 birds. They were fed the starter diet for the first three weeks, the grower diet between the week 4–6, and the finisher diet in the last week 7. Each group was weighed every week during the trial. Feed consumption and feed conversion factor were also recorded weekly, while mortality was recorded as it occurred. The health of birds and their behaviour was under regular control to notice any unusual changing.

RESULTS AND DISCUSSION

The composition of extrudate used in our experiments was based on the composition of poultry offal. Feathers have low nutritional value, especially because of low digestibility. It was partially improved by extrusion, but the improvement by enzymes would be preferable, of course, the price would be much higher, and several problems occur, as it is discussed in the Introduction. High proportion of feet substantially increases the content of ash, which could stress the broilers as an additional ballast component. In future, the mixture of poultry offal with soybean meal would be tested, similarly as recommended by W e n g e r (1995). Such a combination would improve the nutritional value of the product.

Results of the feeding trials are summarized in Table III. The weight increase was only medium as the Astra B chicken used belong to less productive. They were tested because they are common in Poland; the results with more productive hybrids, such as Ross or Cobb, would be still more positive. The experimental results showed that the replacement of meat and bone meal with extruded poultry offal was advantageous from the standpoint of poultry health and safety reasons in the use of broilers as human food. The content of meat and bone meal in the diet was rather high, as the meat and bone meal is the feed component of lowest nutritional quality, but the aim of the experiment was to show the performance in case that all wastes have been utilised. Commercial animal feed (meat and bone meal) is usually produced from utilised (mainly pig and cattle, often dead animals) wet meat wastes, and no producer informs precisely, which raw material has been used during production, and only the protein content is mentioned. Therefore, the production, import and export of animal meal has been recently prohibited in the EU and even in many non-EU countries. Its replacement with well defined

III. Results of feeding trials

Parameter	Age (wk)	Control feed*	Extrusion-cooked feed*	Standard deviation
Body weight (kg)	1	0.08 a	0.09 a	0.031
	2	0.31 b	0.40 b	0.059
	3	0.55 ab	0.62 a	0.082
	4	1.11 a	1.16 b	0.102
	5	1.30 a	1.38 ab	0.090
	6	1.42 b	1.65 a	0.039
	7	1.76 a	1.91 a	0.053
Feed conversion (kg/kg)	1	1.24 a	1.20 b	0.016
	2	1.36 a	1.29 b	0.042
	3	1.46 b	1.40 b	0.071
	4	1.57 ab	1.53 b	0.090
	5	1.79 a	1.79 ab	0.045
	6	1.98 a	1.92 b	0.039
	7	2.14 a	2.06 a	0.042
Overall		1.91 a	1.85 b	0.032

* Average data of 3 groups of chickens (75 birds); a, b – means followed by different letter are significantly different ($P < 0.05$)

poultry wastes from the own production would thus be a big advantage. In addition, the applicaton of extruded poultry offal had positive effect on growth of birds and feed efficiencies. Extrusion cooking itself as a high-temperature short-time (HTST) barothermal treatment effected higher feeding value of processed materials. Birds fed unprocessed control feed performed a little bit worse than those fed extrudates. No significant differences were observed among all groups of birds with regard to their health and mortality. The addition of processed poultry offal to chickens' diet had thus no detrimental effect on birds' performance.

The above mentioned American feeding trials with extruded ground dead poultry used as feed (W e n g e r, 1995) were confirmed in that even high-risk waste materials can be processed by extrusion cooking without negative consequences. In Europe, several objections concerning so-called rapid methods of animal mortality utilization are in focus. The fermentation processing of such materials, proposed by some technologists in the last decade (F e r k e t et al., 1994; M u r p h y et al., 1990; P a e r s o n s et al., 1990), has many advantages, but needs large facilities, and did not find yet large industrial application. In our opinion, a combined technique of deep, long pasteurization, together with barothermal processing, seems to be a proper solution in this field.

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PN-77/R-64820: Pasze. Oznaczanie tryptofanu.

PN-77/R-64821: Pasze. Oznaczanie metioniny w niektórych paszach.

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Využití drůbežích odpadů jako krmiva.

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Při jatečním zpracování drůbeže odpadají vnitřnosti, pařáty, hlavy a peří, jejichž likvidace ve velkoprovozech je spojena s obtížemi. Odpady byly proto rozemlety na velikost částic pod 0,5 mm a zpracovány extruzním postupem na dvojšnekovém zařízení typu 2S-9/5, vyrobeném v ZMCH Metalchem, Glivice, Polsko, při teplotách v intervalu od 65 do 185 °C a hodinovém výkonu 205 kg. Extrudovaná směs byla předehřáta na teplotu 130 °C a pak vysušena při 120 °C na zbytkovou vlhkost 6 %. Výsledný extrudovaný granulát obsahoval 55 % dusíkatých látek (složení je uvedeno v tab. II) a byl přidáván do krmiva brojlerů v množství 8–6 % místo masokostní moučky, o jejímž složení jsou pochybnosti, takže je snaha je z krmivových směsí vyřadit.

Vhodnost extrudovaného produktu byla zkoušena krmným pokusem s brojlery Astra B na dvou skupinách, každá ve třech opakováních po 25 kuřatech. Pokus trval sedm týdnů a kuřata byla krmena *ad libitum* krmivem o složení uvedeném v tab. I. Pokusná kuřata byla zdravá a veterinární kontrolou nebyly shledány závady pro jejich použití pro lidskou výživu. Výhodou extrudované směsi je, že i při kratší době záhřevu, ovšem za vysokého tlaku, hygienická jakost odpovídala požadavkům EU na nezávadnost krmiva. Použití extrudátu mělo příznivý vliv na růst kuřat a na účinnost využití krmiva. Skupiny krmené kontrolní směsí (s obsahem masokostní moučky bez extrudátu) vykazovaly o něco horší výsledky. Výsledky pochopitelně platí jen pro složení extrudátu uvedeného v experimentálním postupu. Mezi zdravotním stavem a úmrtností nebyly pozorovány rozdíly mezi pokusnou a kontrolní skupinou. Potvrdily se tak zkušenosti, které uveřejnil W e n g e r (1995), že ani zkrmování uvedených rizikových odpadních materiálů nemělo po předchozím intenzivním barotermickém procesu nepříznivé účinky a že je výhodné ekonomicky i z hlediska ochrany životního prostředí.

krmivo pro brojlery; drůbeží jateční odpad; extruze

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