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THE EFFECT OF THE EXPANSION FROM THE PRODUCTION TO THE USE OF THE TURKEY GROWING FEEDS

by

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Debrecen, 2007.

1. OBJECTIVES OF THE RESEARCH

In the last one and half decade as a consequence of the development of the nutrition sciences and the emergence and strenghtening of the health conscious behaviour of the consumers the acknowledgement of the nutrition-biological values (fat content, composition of fatty acids, cholesterol content, vitamin and mineral content, quantity and ratio of bioactive materials) of the foodstuffs like meats and meat products, milk and dairy products, egg etc… are becoming more and more important. Furthermore, i.e. considering the production of the products, because of the environment protection animal welfare aspects, increase of quality consciousness, emphasizing of the traditions and traceability, more attention is given worldwide on the breeding and growing conditions of the animals (free range /natural/ or semi free range), on animal feeding, and as in a whole on the quality of the foodstuffs. Although the meat consumption in the developed regions of the world – according to economical forecasts – will not increase considerably in the near future the quality requirements will change and become more stringent, thus further widespread of the products intended for meeting special needs is expected.

Regular meat consumption is very important in the Hungarian nourishing. Due to the meat production projects launched in the seventies the pork and beef meat consumption increased gradually or at least stagnated till 1985 and decreased significantly during the last twenty years. Contrary to this trend the poutry meat consumption steadily increased but within poultry meat consumption the turkey meat consumption increased to a higher rate *(Table 1.*).

Table 1.

Poultry meat production and consumption in Hungary (2002–2006)
(Associacion of Hungarian Poultry Producers, 2006)

Year	Total production	of this turkey production	Total consumption	of this turkey consumption
	1000 tons		kg/capita/year	
2002	640	127	35,1	7,0
2003	631	120	33,2	7,3
2004	606	143	32,3	7,3
2005	551	118	32,0	7,5
2006*	580	127	33,0	8,0

Notice: * estimated value

The appr. 7,5 kg/capita/year turkey meat cumsumption ranks Hungary the number one turkey meat cunsumer in the EU (Germany and France ~6,5 kg, Italy ~5 kg, UK ~4,2 kg) and the number third in the world. Appr. half of the turkey meat produced in Hungary is consumed in Hungary and the other half is exported mainly into the EU markets (UK, Germany, Austria, Italy). The broiler productin shows a decreasing trend, meanwhile the turkey production both in volume and both its share to other poultries are increasing steadily (Associacion of Hungarian Poultry Producers, 2006*)*.

The Hungarian animal production, including poultry sector, in terms of production volume and structure changed after the political transformation. Just before the loss of the Russian market the annual poultrymeat production was 580 thousand tons, from that the broiler production was 400 thousand tons (70%), goose, duck production was 140 thousand tons (24%) and turkey production was only 40 thousand tons (6%).

Feeding of the animals plays a very important role within the chain of the food producing processses, as it might have the most important effect regarding the exploitage of the geneticaly fixed abilities and potentials, and within this, the fulfiment of the requirements of any other stage of the production chain.

The promoting and improrving of the utilization of the nutriments, and the production (also of feeds/diets) under hygienical conditions (one posible solution for that is the in-line heat-processing) are basic requirements in the foodstuff producing chain. During the last ten years *salmonella* elimination from the diets, and the improvement of the digestibility of the nutrients became more and more important for the high productivity farm animal breeds and strains. During this time, in order to replace the conditioning prior to pelleting, expanders were installed, that became quite widespread.

Due to their advantages the thermal/hydrothermal procedures are preferred by the compound feed producers and also by the farmers feeding the animals. The reduction of the energy input of the pelleting may increase the efficiency of the compound feed production, presuming that the installed expander is of the proper size/capacity. Due to the improved quality of the pellets and the improved hygienics of the feeds better results and health status will be achived by the animals, that also confirms the importance of the use of the expanders, that provides for the nutritionists a wider range of raw materials for the composition of the feeds. It is to be taken into consideration, that the increase of the body weight pick up and the increase of feed conversion rate should partly cover the extra costs of the expansion technology and the related investments.

The objective of this work was to establish the complex effect (in terms of feed production technology and animal feeding) of the expander, installed in-line into the technological process of the TAMIX Feed Mill of the GALLICOOP Turkey Producing Pltd (Szarvas).

This technology is a thermal procedure. In the opinion of some people this is a kind of cooking. The real cooking means also addition of siginificant volumes of water, that water later should be removed by a costly procedure. However the hydro-thermal procedure uses the own water content of the material (10–15%), and just minimum water is added in the form of steam. During this procedure the material is also exposed to physical power (due to the high pressure friction heat is generated), thus by this combined procedure an industrial large-scale „cooking" is realized in an economical way. Besides the improved microbiological status and the „side effects", the expansion technique provides further advantages: eg. due to the exposuring of the nutritive substances of the compound feeds the feed conversion rate will increase.

According to the works of PEISKER (1998a) and REICHENBACH (2005) the advantages of the expansion can be summed up as follows:

- improved compound feed quality and digestibility → increase of feed conversion rate
- more fat/oil can be added → hihger energy conent
- harder pellets → better feed conversion rate, less powder, improving health status
- increase of pelleting capacity → improved efficiency of the feed mill
- better microbiological status
- and due to all above facts the efficiency of the animal production will improve.

Because of the more and more stringent regulations regarding the use of additives and grow promoters, those procedures that can be applied without restrictions are becoming more important. For that very reason, all the factors influencing the parameters of the production should be analysed. Some of these factors are the technological develompments in the compound feed production.

These technologies have two effects: one might be realized in the compound feed production and the other in the animal feeding. Both of these effects are investigated in this thesis. On the one hand the technical parameters (technological measurings during the feed production/processing) of the expansion (and/or pelleting) were established; on the other hand the physical, chemical and microbiological analyses and shelf life tests of these feeds were done. I carried out also the *post mortem* investigation of the effect of the heat-processed feeds on the viscosity of the chymuse. Using the feeds processed in this way, the nutrients digestibility was studied by turkeys and two turkey growing-finishing experiments were carried out (for testing the effectivity of production). Using the measuring and experimental results, the expectable advantages upon application of the heat-processing technique, are being estimated by a non-full-scale economic efficiency model calculation. Hereby a serial of experiements was carried out – for that no example was found in the special literature – ie. the same compound feed was followed (traced) from the production to the final using up.

2. PRELIMINIARIES OF THE RESEARCH

Several processes are known how to improve the utilization of the nutritive substances of the compound feeds, but some of them change partly the physical state of the compound feeds. Some of these processes are the milling/grinding, rolling, granuling, steaming, flaking, micronisation, toasting, extrusion, expansion, etc. Due to the heat-processing some of the nutritive substances of the compound feeds are transforming, the microbiological status is improving, and the heat sensitive anti-nutritive substances (eg. soy bean trypsin inhibitor) are being eliminated. The effects might vary considerably also in the function of the dry or wet processing agents.

Special care should be given for the heat-processing, because besides the advantageous effects, some disadvantageous effects might emerge as well, eg. if the transmitted quantity of the heat during the processing and the peak temperature and/or the time of the processing are disregarded. As a consequence the nutritive substances of the compound feed may be damaged (eg. decrease of the availability/digestibility of the amino acids, vitamins, added enzymes, and spoilage of the taste of the feeds, etc…).

KOMKA (2006) gives a complete and comprehensive review about the equipments and techniques of the compound feed production. According to this, the efficiency and profitability of the production of commercial animals are significantly affected by the quantity and quality of the compound feeds and diets eaten by the animals, as feeding accounts 60 – 70 % of the total production costs. First of all the quality is depending on the technical level and technological moderness of the feed mills/plants, producing the compound feeds, concentrates and premixes. The main aspects of the development of the feed mills/plants are as follows:

- adequate storing conditions are to be provided for the storing of the raw materials (components) of proper quantity and quality,
- frequent quality control of the used raw materials (components),
- improval of the technical level, operational and management quality, and relyability of the main and auxiliary equipments,
- gradual application and development of pelleting techniques,
- extension of these techniques and improval of their flexibility,
- provision of the conditions for the addition of liquid components,
- widespreading the application of the heat-processing techniques,
- provision of manufacturing facilities for the production of different compound feeds of physical characteristics being suited to the breed, strain and age of the animals,
- observance of the labour safety and enviromnetal protection related regulations,
- computer aided development of the production and stock management,
- intensification of process quality control.

The primary objective of the modern feed industry is to meet the stringent requirements on product quality and safety. The users are requiring and enforcing new compound feeds of relyable quality, that is not limited just to good mixing accuracy (homogenity) and good pellet quality (PD index).

The reduction of microbiological infection and the elimination of Salmonella infected feeds from the market are basic requirements as well. Thus heat-processing techniques became highlighted. The main factors/parameters influencing the heat-processing are the composition, water content, grain size distribution of the compound feed to be processed, and the temperature of the heat-processing and the time of heating at peak temperature.

The heat-processing technologies in Hungary were applied at fisrt in the eighties. Disregarding the micronisation and roasting trials, flaking („Bocchi" – technology) and extrusion were the fisrt industrial scale applications of the heat-processing techniques. The new techniques were applied first of all for the heat-processing of the full fat soy and basic grain components (wheat, corn, barley) of the compound feeds. In case of soy, the goal was to eliminate the anti-nutritive substances (trypsin inhibitor, urease activity), but in the grains also other kind of changes were achieved: better conversion rate (starch exposure) and strong reduction of the micribiological infection. Generally these technologies had 0,5 – 2,5 t/h production capacity and 300-900 MJ/t specific energy consumption.

Since the middle of the nineties, when the feed mills of larger capacities were reconstructed, the most up to date heat-processing technologies - the expansion and the hygienisation - were installed. The only purpose of the hygienisation was the improvement of the microbiological status of the compound feed, while through the expansion also better nutritive substance/feed conversion rates and the improvement of the physical quality of the pellets were achieved. The expanders and hygienisers of very wide capacity ranges could be applied flexibly by the different size feed mills.

The expansion is practically also a *short time conditioning process at high temperature* (HTST= High Temperature Short Time). This is a rather new procedure for the conditioning of crumbled feeds. These machines are *annular gap expanders*. The machine is similar to the single auger extruder, that consists of thick wall mixing tube, robust segmented auger and steam connection. Recently the expanders are mainly installed directly before the pelleting machine. The liquids (eg. fat and steam) are fed (mixed up) in at the conditioner of the expander.

Some of the advantages and disadvantages of the expander according to the opinion of the feed producers (FAIRFIELD, 1994) are:

- gradual improvement of the quality of the pellet, at the same time increase of production capacity,
- larger volumes (up to 15-20 %) of liquids (eg. molasses or fat) might be added prior to pelleting,

- better hydrolysation of the starch content of the feeds, containing high proportion of grains,
- due to the high temperature and pressure, decrease of the count or complete elimination of the unwanted or harmful germs, bacteriums or moulds,
- the cost of the expander is high, ie. costly initial investment is needed,
- the high temperature and pressure – that is advantageous from other aspects – might limit the utilization of the heat sensitive substances of the feed (vitamines, curative substances, etc.).

Formerly in the expansion techniques (plumping, explosion) the grains were heated with steam – directly (wet) or indirectly by leading the steam into the heating mantle (dry) – in closed space, then after the abrupt opening of the equipment, due to the pressure difference, the grains expanded to the multiple of their original volumes. In the up to date eqipments the periodical operation is changed to continuous operation.

In the Annular Gap Expander, prior to the pelleting, the feed is pre-processed for a short time at high temperature (BECKMANN-TOUSSAINT and METTMAN, 1990). Regarding the structure of the equipment, just the outlet differs from that of the extruder. Applying the expandig technique higher production capacity might be achieved, meanwhile the specific energy consumption is decreasing. Besides the better quality of the pellets, the possibility for the addition of more liquids, the better microbiological status, the better performance of the animals fed with the feeds produced/processed by this technique, the higher flexibility in the composition of the feed recipes are further advantages, though pelleting is not needed for each kind of animals.

Concerning the development and operation of the expander, important informations are available from the works of above mentioned authors. According to their opinion the development of the expander was generated in the compound feed producing industry by the demand on higher capacities and better quality pellets. By using this technology no binding materials (adhesives) and no double pelleting are needed. Due to the capacity increase, the immediate pelleting of the material exiting the expander reduces significantly the energy consumption of the process. The main parts of the expander and extruder are practically the same, only their head units are differing from each other: in the first that is a cone, in the other one that is a matrix. The cone is pushed against the material flow by a variable pressure hydraulic operated expander barrel. The higher is the pressure, the higher is the temperature and vice versa. The pressure of the feed leaving the cone will drop immediately to atmospheric pressure. Significant part of the water — added during the conditioning — will escape spontaneously as steam, thus the matarial cools below 90 °C. The pressure of the cone of the expander is variable in a wide range (0–100 bar), hereby the temperature of the feed is also variable (controlable). The useful working length of the expander varies between 1900-30000 mm, the power supply of the main motor between 45–250 kW/h and the capacity between 3–30 t/h.

After the expander a structurer is installed, from where the crumbled expandate — according to the technological process — flows into the coller either directly (bypassing the pelletizer) or passing through the pelletizer. If needed, subsequently with a Rotospray (heat sensitive) enzymes or other liquids (eg. fat, probiotics) might be added to the final product.

The expansion, regarded as the step prior to conditioning, improves the efficiency of the technology as it makes easier the running of the pelletizer, thus the current consumption of the pelletizer will decrease (thus it can partly compensate the excess current consumption of the expansion). Besides this, that improves also the hygienic status (PEISKER, 1993).

Several authors are remarking additionally to above mentioned facts, that the scientific evaluation of the advantages and disadvantages is till needed. These works were launched already earlier but they are running even nowadays, because data especially regarding turkey growing and turkey feeds/diets are hardly available. Exceptions are the works of MELANDRI (1998ab), PIPA and FRANK (1989) who carried out their experiments (also) on turkeys.

Summarizing the informations available in the special literature, it could be remarked, that they are very comprehensive, but those experiments are missing, wherein the analysises of the feed mill technological details and microbiology of the same feed had been carried out. In the typical experiment arrangements, either just the production was performed and the results of the using were not mentioned, or an animal feeding experiment was carried out, wherein as fact was accepted that the different heat-processings were done.

3. METHODS OF THE RESEARCH

The experimental compound feeds were produced, and the animal experiments were carried out in the plants of the integration of GALLICOOP Pltd.

The compound feeds were produced in the TAMIX Feed Mill of GALLICOOP Pltd (Szarvas), where after ther conditioning the compound feeds were first expanded and after that pelletized.

Machines and equipments used for the expansion+pelleting:

1. Tank (3 m^3)

2. Variable speed auger - speed control by frequency converter

3. 1D-550 conditioner auger (Eco-processor), including 28 pcs mixing paddles + steam and oil/fat portioner. The feed is heated to 72-80 °C, its humidity is 17-18 %.

4. OE.23. Expander: the material of 72–80 ºC temperatrure and of 17–18% humidity flows from the conditioner of the expander into the the expander. With strong simplification the expander might be described as a thick wall pressure-tight steel tube (from this crashing parts are sticking out) with a single shaft segmented auger in it. Through a proper nozzle configuration steam is added by programmed manner into the expander. The crashing parts and the steam are braking together the flow of the feed mixture, thus the material is exposed to strong shearing stress. The mixture warms up and pressure is generated to the direction of the expander end. The end of the expander consists of a sunk annular gap that is closed by a cone-shaped torpedo (piston). The product flows out through the (by the pressure generated) gap between the torpedo and the annular gap. The torpedo is driven axially by a hydraulic expander barrel, that makes possible the fine tuned and instant control of the pressure (that affects the temperature of the material) being generated in the interior of the expander. The pressure in the equipment might be adjusted between 0 – 100 bar, the maximum temperature might be 120 °C. The dwelling period of the material in the expander is appr. 5 seconds, but within this period the above mentioned pressure and temperature remians/exists just for an instant moment. Due to the instant drop of the pressure the main part of the water content of the feed evaporates immediately at the exit end, thus no further drying of the expandate is needed.

5. OE23/30 Structuring rolls: these are two rolls rotating faced to each other, that are forming the expandate – of different shape and dimensions, and tempreture of 90 – 95 °C – exiting the expander, to a shape being suitable for pelleting.

6. Gránit 90 pelleting machine: this machine has a annular matrix and three press rollers. The expandate (80–85 °C) falling down from the stucturer is transfered by an auger into the pellet mill, and the material — of 65/70 °C temperature — falling out from the matrix flows into the counterflow cooler.

7. Geelen VKRS 19X19 pellet cooler

8. RS 700 Rotospray: suitable for the application/addition of different liquids as a final step.

Technological parameters and their recording:

Expansion+pelleting: inlet and outlet temperature of the conditioner (°C), output of the expander (t/h), current intake (A), cone temperature (°C), cone pressure (bar), output of the pelletizer (t/h), current intake (A).

Pelleting: inlet and outlet temperature of the conditioner (°C), output of the pelletizer (t/h), current intake (A).

The parameters were recorded for the digestibility experiment, and during the production of the compound feeds of the growing experiments I. and II..

Measuring of the pellet durability

The pellet durability of 40-40 feed samples — taken from the 2.–8. diets of the first two experiments — were measured with a Kahl-type pellet durability measuring instrument.

Experimental arrangement:

The processings for all the three animal experiments were meaning first of all the method of the heat-processing. In the digestibility experiment expanded, pelleted and expanded+pelleted turkey starter II. diets were fed.

Table 2.

Experimental processings

	Digestibility experiment*	Experiment 1. **		Experiment 2. ***
		with corn	with wheat	
Expanded	X			
Pelleted	X	Ø	Ø	X
Exp.+pell.	X	Ø	Ø	X

* turkey starter II.; ** 8 diets (starter I.-II.-III., grower I.-II.-III., finisher I.-II.);
*** 3 diets (grower III. finisher I. and II.); Ø : without enzyme; X: +with enzyme

The compound feeds (8 diets) fed in the first growing experiment had almost the same nutritive substance content, were based on two types of starch (corn and wheat), were expanded and pelleted and pelleted-only (there were significant differences in the ether extract contents).

The feeds (diets: grower III., finisher I., finisher II.) fed in the second growing experiment were the standard final products of GALLICOOP that were heat–processed through expansion+pelleting and pelleting. In the animal experiments could not fed non-heat-processed feeds, on the one hand because of the different formula, on the other hand the needed volume of oil coud not be picked up by the non-heat-processed feed. For this reason are missing from each experiments the non-heat-processed feeds, the negativ-control processing.

The feeds (starter II.) of the digestibility experiment contained enzyme mixture that was mixed into the premix, while in case of the feeds (3 diets) of the growing experiment II. the liquid enzyme mixture was sprayed by the Rotospray onto the surface of the final pellets. As no enzyme was added to the feeds of the growing experiment I., the measuring of the grade of the (physical) starch degradation became possible.

The feeds of the digestibility experiment were re-milled in order they have the same grain size, otherwise the expanded feed would have consisted of amorphous shape particles. The feeds of the two growing experiments were fed in pellet form.

Laboratory analysis methods: the effect of the heat-processing was studied through the chemical (tests done in the ÁTK/Research Institute for Animal Breeding and Nurition/) and microbiological (tests done in the OMMI/Natilonal Institute for Agricultrural Qualification/) change of the compound feeds.

The Weendei analysis of the compound feeds: alltogether 48 samples (2x3x8, „with corn" and „with wheat", non-heat-processed, expanded+pelleted, pelleted) taken from the eight diets of the growing experiment I., and 6 samples (3x2, expanded+pelleted and pelleted) of the growing experiment II. were chemically analysed.

The extract content of the compound feeds were determined according to MSz (Hungarian Standard) 6830/3:1993, the crude protein content according to MSz (Hungarian Standard) 6830/4:1981, the ether extract content according to MSz (Hungarian Standard) 6830-6:1984, the crude fibre content according to MSz (Hungarian Standard) EN ISO 6865:2001, the crude ash content according to MSz (Hungarian Standard) EN ISO 6865:2001, the gross energy according to MSz (Hungarian Standard) EN ISO 9831:2004 calorimetric method.

Besides the above mentioned analysises carried out within the scope of the digestibility experiment, the starch content of the feed and chymuse samples were determined according to the standard MSz (Hungarian Standard) 683/18-1998. The uric acid content of the chymuse samples were determined by the KRISTEN and POPPE (1966) phosphoric-tungstic acidic method, and the ammonia content with NH_3-sensitive electrode (Radelkis OP 242-2).

Measuring of water activity: this is a quite new and very fast method for the forecasting of the microbiological stability of the compound feeds. The water activity of the diets, fed in the growing experiment I. was determined in the samples that were taken from the diets just after their production.

Microbiological tests: the microbiological status of the feeds were analysed because of two reasons: the one was to determine the shelf life of the feeds, the other was to ensure that the feeds are safe for the animals („food and feed safety").

The aerob mezophil bacterium flora (total bacterium flora, total viable count) was determined according to MSz (Hungarian Standard) EN ISO 4833:2003, the total mould count according to MSz(Hungarian Standard) ISO 7954:1999, the Enterobacteriaceae sp. according to MSz (Hungarian Standard) ISO 7402:1999, the Salmonella according to MSz(Hungarian Standard) EN ISO 6579:2002. Microbiological tests were done also on the main components of the 3 diets (12 samples). The above mentioned test/analysis methods were applied, and the analysis/test results were evaluated according to the instructions laid down in the Appendix of the FVM (Ministry of Agriculture and Rural Development) decree No. 45/2001. (VI.25) respectively in the Appendix No. 20. of the FVM (Ministry of Agriculture and Rural Development) decree No. 43/2003 (IV.26).

The effect of the production technology on the microbiological status of the fresh samples was analysed in alltogether 18 samples taken from the starter I., grower II. and finisher I. diets of the pelleting and expanding+pelleting processings (from corn and wheat based feeds).

Alltogether (2x3x3) 18 samples from the starter I. diets (corn and wheat based, non-heat-processed, pelleted and expanded+pelleted) were analysed for bacterium flora, mould count, Salmonella and Enterobacteriaceae.

Measuring of acid count and peroxid count: they were determined — according to the analysis method No. 2004-III-7 laid down in the Hungarian Feed Law — in the samples taken from the diets (48 samples) of the growing experiment I.. These samples were taken: just after the production of the diets, after 30 days and after 60 days.

Amino acid tests: the total amino acid content was determined — according to the instructions laid down in the article 7. „Determination of amino acids by ion exchange chromatography„ of the Appendix No. 10. of the FVM (Ministry of Agriculture and Rural Development) decree No. 44/2003 (IV.26) — in the samples taken from satrter I., grower I. and finisher I. diets of different processings (2x3).

Determination of the utilizable lysine: the potentionally utilizable lysine (its amino group in the epsylon position is free) — from chemical point of veiw — in the animal organ was determined according to MSz (Hungarian Standard) 6830/32-82402:1999.

Measuring of the protein and N-solubility: in order to establish the grade of the protein denaturation, the water solubility of the protein and N were measured, and the protein (PDI) and the N solubility index were determined. The AOAC methodes (S BA10-65 and S BA11-65) of the determination are published in the book of HEGEDŰS et al. (1981).

In vitro measuring of the digestible crude protein content: the digestible crude protein content of the feeds was determined according to the method laid down in the MSz (Hungarian Standard) 6830-5:1987.

The α-amylase availability of the starch content of the feed: I wanted to determine the such types of heat-processing effects through the determination of the potential (bacterial origin) α-amylase availability of the starch content of the feed. For this measuring a new method was developed with my cooperation in the ÁTK Microbiological Laboratory (was published in 2007 by MÁTRAI et al.). The essence of this procedure is that the maximal (bacterial origin) α-amylase avaialbility of the starch content of the non-heat-processed samples is determined through their cooking, and then the potential availability of the starch content of the samples, heat-procesed in a different manner, will be compared to that of the cooked samples. The measurings were carried out on 48 samples taken from the feeds, fed in the growing exp. I.

Feed viscosity: the effect of the heat-processing on the viscosity (that has an essential correlation to the degree of the gelation) of the feeds (moistened according to the heat-processing techniques) was established on the Department of Biochemistry and Food Technology of the Budapest University of Technics and Economics. The method is described in details in the article of JUHÁSZ and SALGÓ (2006). Samples were analysed two times, first the heat-processed (in itself) corn and wheat meals (the grain base components of the feeds) were analysed, and second the corn and wheat based compound feeds (starter I.) of the growing experiment I. were analysed (non-heat-processed, pelleted, expanded+pelleted).

Measuring the viscosity of the chyme: the measuring method is practically the same that is applied for the feeds, the only difference is in the preparation of the samples. Here were taken into consideration the proposals of WIESMAN (1990) and SZŰCSNÉ et al.(1999). The measurings were carried out on the samples taken from the small intestines, collected upon slaughtering of the turkeys (of 11 weeks age, n= 2x2x6) from the grower II. phase of the growing experiment I. After the proper preparation, the samples were placed into the viscosimeter and the measuring was carried out according to the above mentioned method.

Animal experimental methods:

The method of the digestibility experiment: the experiment was launched in the experimental farm of the Georgicon Agricultural Department of the Veszprém University, taking into consderation the proposals of two European reference methods (BOURDILLON et al., 1990 ab). 28 day old male turkeys (B.U.T. BIG 6) of 1230+/-240 g body weight — originating from a brooding farm of GALLICOOP Pltd. – were placed by 3x(2x8) arrangement (3 heat-processings: granuled, expanded and expanded+granuled; 8 animals per heat-processings — individually placed, in two repeatings). The heat-processed compound feeds were re-milled and were fed in crumbled form. The method of VINCZE (1999) was applied for the calculations (digesting coefficients, N retention).

Method of the growing experiment I.: arrangement by 2x2 factors, 6 birds per repeatings. Factors: production technology (pelleted and expanded+pelleted), and type of the diet recipe (source of the grain: corn and wheat). The experiment was launched in May 2006 on the Turkey Brooding Farm No. III of the Habar Ltd — that belongs to the integration of GALLICOOP Pltd. — with Hybrid Converter (Hybrid Ltd, Canada) male turkeys. The experimental brooding was performed in the live age period of 17-52 days, in such a way that the 48 cages (of 1 m^2 ground area, and of 100 cm height dividing wall) were installed into the barns working under normal production conditions (12, 6 birds/cage per heat-processigns).

At the live age of 52 days the birds and the cages were transported to the Örökföld Turkey Growing Farm of Goldfood Ltd in Újkígyos, where the growing was finished (between the live age of 52 and 135 days, but with 2 m^2/6 bird ground area). At the launching and finishing of the experiment, and at the changes of the diets — alltogether at 11 cases — the turkeys were weighed individually.

The feed intake was recorded by each cage and by the change of the diets. The slaughtered animals were qualified at the slaughtering plant.

Method of the growing experiment II.: 2 heat-processings, 12 repeatings per heat-processings, 5 brooded birds (Hybrid Converter, Hybrid Ltd., Canada) per repeatings. Experimental factor: production technology (pelleted and expanded+pelleted). At the end of the technological process enzyme was added with a Rotospray. This experiment was carried out also at the Örökföld Turkey Growing Farm of the Goldfood Ltd in Újkígyós under the same growing conditions as that of the other experiment, but just in the last growing period (from the live age of 84 days to 126 days). The birds were weighed seven times. The feed intake was also recorded by each cage and by the change of the diets. The slaughtered animals were qualified at the slaughtering plant.

Biometrical and economical calculations: the biometric calculations (basic statistics, variance analysis, T estimation) were done with the SPSS program. For the non-full-sclae economical calculations descriptive statistics was applied, for that the data were provided by the accounting, controlling and agricultural departments of GALLICOOP Turkey Producing Pltd. (H-5540 Szarvas, Ipartelep 531/1).

4. MAJOR CONCLUSIONS OF THE THESIS

The fundamental objective of the experiments, described and explained in this thesis, was to analyse the compound feeds (in my case the turkey feeds were the example) upon heat-processing – expansion and pelleting or pelleting-only. These techniques have two effects: one might be realized in the compound feed production and the other in the animal feeding. Both of these effects are investigated in this thesis. On the one hand the technical parameters (technological measurings in the feed mill during the feed processing) of the production are being established, on the other hand the physical, chemical and microbiological analyses and the shelf life tests of the different diets were done. Using the heat-procesed feeds, the nutrients digestibility was studied by turkeys, and two turkey growing-finishing experiments were carried out (for testing the effectivity of production). Using the measuring and experimental results the expectable advantages upon application of the processing techniques are being estimated by a non-full-scale economic efficiency model calculation.

The expansion is a quite new technique in the feed production, while pelleting is quite old. Despite informations about both of these techniques are available (more detailed description is given by GUNDEL, 2003; KOMKA, 2006), few (PEISKER, 1998b, MELANDRI, 1998ab) just few or maybe no work is available, that would had analysed jointly the technical parameters of the production and the biological utilizzability in case of all aspects, ie that had investigated the same feed during the processing, storing and during the turkey growing experiment.

In this thesis data about the production of 12 turkey diets — produced for the animal experiments — are being collected. These data are highlighting what a fast processes they are: the dwelling period is 10 seconds in the conditioner, 5 seconds in the expander and only 5 seconds in the pelletizer. Here, and also when the feed is exiting from the expander — due to the „explosion" caused by the generated pressure difference — processes take place, whereby some substances in the feed are restructured. Such changes are both advantageous and disadvantageous. According to the experiences of the feed mill the feeds – depending on their composition (e.g different type of grains) – are behaving in a different way during the processing. These factory experiences were just partly confirmed by factual measurings, because regarding the measured parameters of the heat-processings (conditioning, pelleting and expanding+pelleting) no significant differences were observed, the temperatures and the dwelling periods were practically the same. That is easy to understand, because the process control computer controls these parameters. It is important within this — and regarding the efficiency of the feed mill this is a crucial factor — that the specific power consumption of the expansion+pelleting is almost three times higher than that of the pelleting. But after the expansion the specific power consumption of the pelleting is 16–22% less than that of the pelleting-only. That means also a 1,5–2 t/h capacity increase (depending to some extent on the composition of the produced feed) of the equipment.

According to the opinion of the engineers of the feed mill, this increase of the capacity will more than compensate — in a feed mill-scale — the extra power consumption and extra costs of the expansion. These conclusions are partly in accord with, but partly differing from the opinions of the special literatures (eg. FAIRFIELD, 1994; LUCHT et al., 1998a).

Besides the peak temperatures reached, the quantities of the transfered heat were estimated as well, because that affects also the processes. Heat is transfered (addition of steam) only in the conditioner and in the expander. According to the calculations with the measured parameters, almost 30 % more heat is to be transfered to the processed material, if it is expanded prior to conditioning. That might be the explanation of the differences in the starch gelation, but that should be analysed also within further researches, as no data was available in the special literature regarding this subject.

The properties — namely the pellet durability, crumbling susceptibility — of the final product pellets are depending on the modifications due to the heating. In that case, especially the different degrees of the starch gelation are resulting different adhesing efficiency, and here similar results were achieved like by FAIRFIELD, 1994; KOMKA, 2002; and BENCSIK, 2004. But the in-line measurings showed that this is affected first of all by the fat content of the feed. Finally could be established that in case of high total fat content, the durability of the pellet that is made from a previously expanded feed, is 7–11% higher than that of the pellet produced just after the conditioning. The special literature (PAYNE et al., 1994; POEL, 1989; KOMKA, 2006) of the pellet durability considers mainly just the gelation ability and the added adhesives (molasses), and just mentions that the pellets made of high fat content feeds will be softer.

The standard Weende analysis of the feeds - as it could be expected - did not show any change after the processings.

The change of the fibre content of the diets was analysed as well, but no related data is available in the special literature. According to CLASSMEN and BEDFORD (1991) the heat-processing is affecting the quality, that is — according to the opinion of SUNBERG et al. (1995) — due to the lessening activity of the enzymes, that inhibits the degradation of the fibre. Regarding the proportion trends of the recorded data, there is no difference between the non-heat-processed and heat-processed samples (pelleted and expanded+pelleted). If the presumption of SUNBERG et al. (1995) is accepted, it could be understood why the TDF and jointly — the earlier achieved proportions being maintained — the quantity of the soluble fibres are increasing because of the heating. It is difficult to explain why the hemicellulose content increases because of the heating. Anyway further investigations are needed for the explanation of these phenomenons.

As the effect of the different heat-processings on the proteins/protein fractions in the feed is well known, they were investigated separateley.

The crude protein digestibility was determined *in vivo* and *in vitro* as well, but there were no differences between the heat-processings. These results are in accord with the results published by MELANDRI (1998a), and might be an explanation that the crude protein (Nx6,25) is not an exact enough approach of the problem, protein solubility and amino acid analysises are needed to this.

There is a significant difference between the digestibility coefficients determined by the two methods, that might be explained with the fact that the *in vitro* method is for general purposes and is not poutry (turkey) specific.

The Protein Dispersibility Index (PDI) and the Nitrogen Solubility Index (NSI) are showing the ratio of the protein and nitrogen that remained in water solution from the total protein and nitrogen content of the heat-processed feed. According to the special literature the HTST processings might decrease this index, that is due to the inclusion because of the high degree of starch modification (the higher the original protein content - eg. in case of leguminous plants - the higher is the value). The analysis of the 48 samples, taken from the diets fed in the first growing experiment, confirmed the opinions found in the special literature (PEISKER, 1992; GINSTE and DeSCHRIJVER, 1998), according to that if the heat-processign is more intense the PDI and NSI decreases. Though the decrease is mainly significant, it is not to be regarded important, because for this the values should exceed the 20 relative % (HEGEDŰS et al., 1981) that is 9,5 and 19,2 % in case of the PDI, and 17,0 and 18,2 in case of the NSI (corn and wheat based compound feeds). The higher values of the latter are meaning remarkable differences between the corn and wheat based compound feeds, thus might be concluded, that heat damages the corn based compound feeds to a higher extent (among other things that might be an explanation that in the growing-finishing experiments why higher performances were achieved with animals fed with wheat based compound feeds).

According to the expactations, regarding the amino acid content of the samples of different heat-processings no siginificant difference was remarkable. But this opinion of mine is not in accord with that of MELANDRI (1998a), who regarded the differences – that were even smaller than my values – as a result of the processings.

Due to the so-called Maillard reaction, the heat-processing of the feeds might have one negative effect: some amino acids might become indigestible for the animal organ. The lysine aavailability was determined by stain-binding method, and no significant changes were established after the heat-processigns, because they did not reached extreme values. This corresponds to the opinion published by MELANDRI (1998a), according to him the amino acids are heat damaged only if the temperature exceeds the 130 °C.

The own enzymes of the organ are able to digest the starch but not the NSP. In the (Weendei) crude fibre analysis the NSP is partly in the crude fibre fraction and partly in the Nitrogen Free Extract, that is to be explained with the different solubilities of the NSP-s.

Besides the total NSP content the water soluble part of the NSP is an important factor as well, because the NSP is influencing the digestive tract, mainly through developing higher viscosity. The heat-processings (eg. pelleting) applied in the feed production are affecting the quantity, solubility and viscosity of the NSP-s (CLASSNEN and BEDFORD, 1991), moreover SUNBERG et al. (1995) are assuming that the activity of the endogene enzymes in the grains are decreasing, that inhibits the degradability of the fibres, and increases the viscosity of chyme. In my experiments I could determine the *post mortem* viscosity of the chyme in the 11 weeks old turkeys originating from the growing experiment I.. I established that with the wheat based compound feeds and with the expansion+pelleting heat-processings the values were higher. For the comparision of the values no data was available in the special literature. The only known fact is that corn is generally not increasing the viscosity of chyme (OROSZ et al., 2006), and wheat is generally increasing it (JEROCH et al., 1993; CHOCT et al., 1996; DUSEL et al., 1997).

Several characteristics of the starch content of the feeds were investigated. The α-amylase availability of the starch was determined by a method that was developed within the scope of this work. The hypothesis of the measuring was that the heat-processing initiates the degradation of the starch grains and that provides favourable conditions for the α-amylase enzyme, that is the most important strach degrading enzym operating in the organ. At first the potential 100% availability was determined in non-heat-processed samples, and the values determined in the different samples were compared to this value. It was established that pelleting and expansion+pelleting significantly increase the availability but not to the expected extent. The original appr. 11% availability of the non-heat-processed samples increased to 17,4 and 21,6% in case of the wheat based samples, and to 22,6 and 26,8 % in case of the corn based samples. The rate of it in case of the former was 51 and 87%, and in case of the latter was 107 and 146%. The presented values are important from the animals' point of view, but it is doubtful if they are feasible, significant changes. This is confirmed by the experience in the turkey growing-finishing experiment, where significant improvement of the apparent digestibility of the starch (anyway that was rather good) could be achieved only by expansion+pelleting.

The degree of the starch degradation might be determined also by measuring the viscosity of the suspension prepared from the heat-processed feed. The shape of the so-called RVA curves — that is the basis of the evaluation — varies in the function of the amilose/amilopectin ratio of the starch in the feed, and in the function of the quantity and availability of the starch grains. The corn and wheat samples reacted to the heat-processing in a different manner, presumably due to the difference between their starches. The expansion slightly increased the peak viscosity of the corn sample, and only the granuling decreased it, while the dual processing increased it significantly. In case of the wheat samples a fully evident trend could be established: the expanded+pelleted sample had the highest measured viscosity at all, after that the pelleted-only and the non-heat-processed samples. The absolute values and the differences between them are higher in this case, than in the corn, indicating that in case of wheat starch a higher rate of gelation is to be expected than in the case of corn. This is backed up also by the empiric experinces gained in the feed mill.

Besides the degree of the starch degradation also the fat content and other components might strongly affect the viscosity of the compound feeds. For that very reason — though the trends are the same — the viscosity values are significantly lower. There is no or very little experience in the viscosity investigation of such, ie. compound feed samples, thus further biological, physical and starch-chemical analysises are needed in this subject.

It is known from the special literature that the different heat-processings are strongly affecting the shelf life, microbiological stability, microbiological status of the feeds. In my experiments these effects were traced and invstigated.

In the first analysis of informatory nature the water activity of the non-heat-processed and heat-processed samples was measured. In case of each measuring the results confirmed not only the good quality of the feeds, but also that batches of the same quality like the sample will have a law risk to microbiological spoilage.

One of the objectives of the hydrothermal techniques is to destroy possibly in full the harmful bacteriums. For that certain time, temperature, humidity and pressure are needed, and each of these factors have also their distinct effects. At the end phase of the expansion process the pressure drops instantly: the 40 bar internal pressure before the exit annular gap will drop to atmospheric pressure upon the material leaves the annular gap. Because of this the permeable membranes of the microbes will practically explode (PEISKER, 1994b; THOMAS and POEL, 2000). The actual microbiological analysises were preformed with two objectives. The one was measure the microbiological status of the fresh samples (raw materials and the compound feeds after heat-processing), and the other was to measure the same parameters by the expanded+pelleted and by the pelleted-only samples, but only after one and two months storing (at room temperatue). With the first analysis the measured water activity results could be just confirmed, and some higher values of mould counts were within the maximum limit. The analysis of the full compound feeds was also confirming the good quality, but in such a way that the mould count dropped by one order of magnitude by each sample, taken from the expanded+pelleted and pelleted-only corn based feeds. This kind of drop might be established just by the starter I. diet of the wheat based feeds, and the extent of the drop was two orders of magnitude.

The shelf life test evidenced that the heat-processing — due to its general effect — improves the shelf life and microbiological stability of the feeds. While the microbiological status (total viable count and mould count) of the non-heat-processed samples worsened, that of the heat-processed samples did not change, thus good shelf life is expected for the expanded+pelleted and pelleted-only feeds.

At the same time with the microbiological measurings (0., 30. and 60 days), also the acid and peroxid numbers of the feeds were determined, that have very great importance in case of compound feeds of such a high fat content. Considering the official maximum limits (acid number 50, peroxid number 25), all the test results of the fresh samples were satisfactory, moreover the test results of the samples stored even for one and two months did not exceed the critical value. But besides this, such a trend might be observed that the values are the highest in the non-heat-processed samples, after that in the pelleted ones, and are the lowest in the expanded+pelleted samples. Regarding the acid numbers (the quantity of the free fattic acids might be estimated with it) significant changes were observed due to the oil content of the feeds and due to the technology. At the end of the two months storing period the acid number of the non-heat-procesed corn based feed samples exceeded the critical value, while the acid number of the heat-processed samples did not.

Big change might be observed in case of the wheat based samples, because they contained appr. 10% more ether extract (partly mixed in, partly added by Rotospray). The acid number of the non-heat-processed sample increased to the double after one month, thus exceeded the critical value, and to the end of the second month the value increased to the 267% of the original value. The value increased relatively fast also in the pelleted sample, but the value 50 (220%) was exceeded only at the end of the second month. The values of the heat-procesed samples after 1 and 2 months were significantly different from that of the non-heat-procesed. The values of the expanded+pelleted sample were very good even at the end of the shelf life test.

The phenomenon — namely — that the peroxid number increases practically just to a minimum extent, while the acid number to a higher extent, might be explained with the fact that the oil added to the feed was likely to become labil due to the processings applied during its production. As a result of this, the enzymatic hydrolysis processes were initiated even itself (non-heat-processed feeds), then the pelleting and expanding+pelleting decreased the extent of the hydrolysis due to the damage of the enzymes. That explains also the higher value by the wheat based feeds, because such fat was added (with Rotospray) to these feeds that were not additionally heated. Important to notice that though the acid number values several times exceeded the critical limits to a great extent (ie. being not conform to the relevant legislation/law they could not be placed on the market), that will not deteriorate the utilizability of the feeds, because the birds are compensating well the more „acidic" feed.

Besides the *in vitro* measurings the effects of expandsion+pelleting and pelleting-only were investigated also in animal experiments.

No work was found in the special literature that investigated jointly the effect of the expansion+pelleting and pelleting-only on the turkey related digestibility and digestible or metabolisable energy of the feeds. That is why was determined the apparent digestibility and metabolisable energy of the nutritive substances of the starter II. diet fed in the digestibility experiment, that was carried out with turkeys, Three types of feeds were fed: expanded, pelleted and expanded+pelleted. Like in the *in vitro* measurings, no difference could be established regarding the crude protein digestibility, and that confirms that the applied heat-processings did not damage the feed proteins. Regarding the ether extract digestibility no difference was generated by the expansion-only or by the pelleting-only, but the expansion+pelleting resulted significantly better digestibility by both of them. Similar proportions and trend could be established by the starch digestibility. Regarding the to 0 nitrogen retention corrected apparent metabolisable energy (AMEn) of the tested feed, the differences were relative small but significant. The lowest value was measured by the expanded-only feed, while the highest by the expanded+pelleted one. According to the results of the digestibility experiments, it could be established that, due to the additive effect of the expanding+pelleting, the digestibility of the nutritive substances and the AMEn value of the feed evidently increased.

Two turkey growing-finishing experiments were carried out with granuled and expanded+pelleted feeds. According to the general practices of the turkey growing eight diets were fed, of that one serial was wheat based and another was corn based, in order the expectable differences could be realized with more certainty. Each feed of the experimental processing was fed by 6-6 birds (n=2x2x(12x6) say 288), in 12 repeatings between the live age of 17 and 135 days. The lenght o the second experiment was shorter, the last three diets (grower III., finisher I. and II.) were feeds used by the integration, they were fed in pelleted-only and expanded+pelleted forms also in 12 repeatings (n=2x(12x5) say 120), between the live age of 84 and 126 days.

In the period of 87–102 days (grower III.) the first experiment – as systematic error – was disturbed by an extreme hot weather period, thus all the investigated prameters were declined, but that was compensated by the birds in later days/weeks. No significant deviation in the body weight gain of the birds was developed, neither in case of any diet nor in entirety. According to the data, higher (but just slightly) values were achieved by the expanded+pelleted feeds. In case of the wheat based diets grower II., III. and finisher I. , and corn based diet finisher III., only those birds have achieved better perfomance which were fed with granuled-only diets.

The voluntary feed intake of the birds (and of course all other species) is a very important preconditon of the production. It is difficult to explain that in the experiment contrary trends could be observed between the birds fed with corn and wheat based diets: in case of the corn based diets the intake of the expanded+pelleted diets were higher and in case of the wheat based diets the intake of the pelleted-only diets were higher. In whole, the daily intake of the wheat based diets was higher than that of the corn based diets.

The feed conversion rate (the quantity of the feed consumed per one kg live weight (upon slaughtering)) differences between the processings are not too big, generally this value is better in case of the birds fed with expanded+pelleted feeds than is case of the birds fed with pelleted-only feeds. Here could be observed the unfavourabe effect of the hot weather period as well, and the compensation period following.

Summing up the results of the whole growing-finishing period, the best results (but not significantly) were achieved by the birds fed with wheat based feeds of expanded+pelleted processing: they achieved the heaviest finished live weight, the best daily gain of body weight and the best feed conversion rate, in particular at a rather high level of average feed intake. In the other experiment with the wheat based processed feeds the body weight gain was also very good, but the feed conversion rate was the worse, because the feed intake was the highest by these feeds. In the experiment with the two corn based processed feeds, the results achieved were evidently better by the birds fed with expanded+pelleted feeds. In case of each processings the yields of the valuable meat parts (drumstick, thigh, breast) were proportional to the live weight upon slaughtering, no differences — due to the feeding — could be established.

The results of the second experiment were also similar to each other, but the differences were significant. In spite of this, the differences in the body weight gain were minimal, the initial weight differences remained during the whole period of the experiment. Except one live period, always significant differences were measured — $P \leq 0,05$ (20–60 g/day/bird) — among the daily feed intakes of the birds, and the values were higher in case of the pelleted-only diet. As a result of the small differences among the body weight gains and the smaller intake from the expanded+pelleted feeds during some live periods and during the whole, the feed conversion rate differences were significant — $P \leq 0,05$ — due to this processing. The quantities of the valuable meat parts were the same by the processings.

It might be established in general that due to the better feed conversion rate because of the smaller feed intake, the feeding of the expanded+pelleted feeds are to be regarded as reasonable. Further experimental works are needed — taking into consideration the experiences of both experiments — concerning the conclusions regarding the feed intake (decrease).

The results of the growing-finishing experiments were hardly differing from the data of the special literature, though nothing was published about turkey growing experiment. The experiments carried out with broilers (earlier JACKSON, 1994; later DOUGLAS and PARSONS, 2000; CAMPBELL et al., 2006) and with pigs (O'DOHERTY at al., 2001ab; REICHENBACH, 2005), resulted mostly no meaningful improvements. In spite of this the authors agree, that because of some other advantages (easier production, improvement of microbiological status) the feeds for the monogastric animals are to be expanded first and after that are to be pelleted.

The results of the performed small-scale informative economical evaluations are indicating the need for a comprehensive economical analysis on the full technological process (production, turkey growing), because there are several interactions (physical, chemical and/or biological) within the processing technology, that might influence the direct production costs, the production costs of the live birds and the overall economical efficiency of the producing integration. Some of the main cost elements are the specific raw material and energy cunsumption, including the power/electricity consumption of the machines, equipments (that is especially highlighted by HERRMAN and LOUGHIN, 2003), and the feed transformational abilities/potentials of the animals.

Evaluating all the analysises and tests of the experiments, the expansion+pelleting technique might be regarded as more successful than the pelleting-only, first of all because of the advantages in the feed production. Some of these advantages are: eg. because of the 1,5–2 t/h capacity increase the number of the working shifts might be reduced by one, the easier working organization and the related cost savings. Underlining these, the improvements of the animal production costs efficency (that on the full integration scale would total already several hundred million HUF in cost savings) are meaning further advantages.

5. THE NEW RESULTS OF THE THESIS

1. Due to the expanding and pelleting – according to the crushing test results – the pellet durability increases by 7-11 %, independently of the quantity of the fat added to the feed
2. Due to the dual effect of the heat-processing the decrease of the PDI and NSI is less than 20 %, that from biological point of view might not be regarded as meaningful (the critical point is 20 %)
3. The viscosity of the chyme in the 11 weeks old turkeys fed with expanded+pelleted feed increased by a higher extent if wheat based diets are fed, and to a smaller extent if corn based diets are fed
4. Due to the effect of the expanding+pelleting, the α-amylase availability of the heat-processed feeds increases to 21,6–26,8%, contrary to the 11% value of the non-heat-processed sample (that is in case of wheat based compound feeds 87- , in case of corn based compound feeds 146% increrase)
5. The viscosity of the wheat samples is higher than that of the corn sample, and the viscosity of the expanded+pelleted samples is higher than that of the expanded-only or pelleted-only or non-heat-processed samples.
6. The viscosities of the compound feeds have a similar trend like the pure cereals, but at lower values, because besides the gelation of the starch that is affected also by other components (fat, total NSP, etc.).
7. The expansion+pelleting prolongs the shelf life of the feeds: according to the microbiologcal and peroxid number/acid number analysises the heat-processed compound feeds have at least two months shelf life
8. According to the digestibility experiments carried out on turkeys, can be established that the slight improvement of the protein, fat and starch digestibility, due to the expanding+pelleting, is sufficient for the significant increase of the AMEn value (also in turkey) of the feeds heat-procesed in such a manner

6. POTENTIAL APPLICATIONS OF THE RESULTS IN THE PRACTICE

1. The expanding and after that the pelleting of the (turkey) feeds should become a generally applied technique in the feed production, because this is the only technique that makes possible the production of feeds meeting the requirements on energy and protein content and hygienics;
2. The experimental work should be extended also over the turkey related unknown factors. These are the effects of the heat-processings of different times, temperatures and pressures on the:
   - protein/amino acid and starch content of the feed components and compound feeds;
   - digestibility of the nutritive substances;
   - degradability/digestibility of the starch;
   - viscosity of the feed;
   - microbiological status and shelf life of the feed;
   - performance of the turkeys of different ages and sex.
3. The preparation of a large-scale economical evaluation on the full technological processes (including investment and operational costing) would be important and interesting.

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