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Calculation model for the assessment of animal by-product resources in Estonian meat industry

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Abstract. Aim of current study was the elaboration of a calculation model for monitoring system which makes it possible to assess the animal by-product (ABP) resources in cooperation with companies and state authorities. Data about quantities of processed animals by species were collected from existing public databases, Estonian Animal Waste Processing Plant and meat processing enterprises of Estonia. Data from scientific literature and available statistics as well as data about the quantities of meat and slaughtering products observed in slaughterhouses was used for estimation the average of ABP quantities per animal by species. Based on these two datagroups – number of animals (by species) and yield of ABP per animal during meat processing, functionality of the general calculation model for monitoring was tested. Inputs for this model are numbers of animals by species and outputs accordingly the quantities of ABP by risk-categories and types. During evaluation of the calculation model it was estimated that nearly 22 thousand tons of ABP are generated in the recognized slaughterhouses of Estonia annually. 1,900 tons of it consists of 1st category ABP, 3,400 tons 2nd category and over 17,000 tons 3rd category ABP. On the other hand quantities of ABP delivered from meat industry to the reprocessing as a 1st category was 4,900 tons which exceeded the estimated (by calculation model) amounts about 3.5 times. Thus a great deal of other ABP categories had also been sent for reprocessing as the most dangerous waste. This fact indicates to the insufficient use of 2nd and 3rd category ABP as raw material in Estonian meat industry. Existence of an efficient monitoring system will promote the management of ABP recourses in slaughterhouses and meat processing companies. For this the relevant databases, procedures and methods should be worked out.

Key words: animal by-products, meat processing, monitoring system.

INTRODUCTION

The deficit of protein, including protein of animal origin, is particularly high. Animal proteins suitable for human consumption comprise less than one-third of the total food protein 'fund' available globally (FAOSTAT 2013). On the other hand, there is also an increasing need in protein sources for animal feed production (Boland et al., 2013). At the same time, the amount of protein lost during meat processing is unreasonably large – up to 30% protein suitable for human consumption (Sannik et al 2013). This is caused by the methods commonly used for industrial meat processing, especially in treatment of the animal by-products (ABP). Latter are usually utilized for fat production, for technical purposes or destroyed for safety reasons (Pearl, 2004).

According to EU regulations (Regulation EC. 2001, 2009) ABP has been categorized into three main categories according to the possible health risk. 1st and 2nd categories of ABP are classified as high risk materials and 3rd category as low risk materials. So the use of the 1st category ABP in food- or feed-chain have to be eliminated totally, due to the TSE risk. A limited use of the 2nd category ABP for the composting or technical purposes is allowed. Use of the 3rd category ABP is allowed for many purposes: for composting, for technical purposes, for feeding and in limited forms for food. At the same time some authors (Ockerman & Hansen, 2000; Arvanitoyannis & Ladas, 2008) suppose that getting all of requirements together at one time in one place is not always an easy task. Detailed principle of ABP categorization etc. is given in EU regulations.

Relevant institutions have settled strict rules for handling of different ABP categories, how these can be collected, stored and transported, and how these can be treated, used and disposed in EU member countries (Juste, 2010). Especially by-products that are unsuitable for human consumption may pose at wrong handling serious risk to the health of people and animals. This has been confirmed by several earlier crises: the outbreaks of foot-and-mouth disease, the spread of the transmissible spongiform encephalopathy and the dioxin compounds in fodder (Segarra & Rawson, 2001). These crises were caused by the incorrect use or handling of certain ABP, which resulted in re-entering those into food chain. ABP may also harm the environment and biodiversity due to handling problems.

Many papers describe a variety of assurance initiatives, and explore how targeted research and development can be used to provide the successful managing of food safety and quality risks in meat production (Ockerman & Basu, 2004; Olgo, 2011; Lehto, et al., 2012). At the same time, a fully integrated assurance system, with effective control applied at all stages in the production chain is not at present achievable in all but a few operations (Toldra et al., 2012; Sannik et al., 2013). Constant monitoring of ABP will definitely help in solving the problems of food safety assurance.

The utilization of ABP is becoming an increasingly critical issue because of rising consumption of meat and growing quantities of ABP generated by slaughterhouses as well as the increasingly strict requirements and prohibitions established for the handling and use of ABP. Use of ABP as a raw material for biogas production seems to be promising at present, as gas can be utilized to generate energy (heat and electricity or fuel) locally (Marcos et al., 2010). This enables also co-use of plant resources for bioenergy production in a more efficient way (Juste, 2010). However, it should be emphasized that use of pure ABP as raw material for biogas production without specific knowledge is likely to cause a drastic drop in the efficiency of the process and an

unpleasant odor problem (Pitk et al., 2012). On the other hand, there would be an active market and high demand for the 3rd category material produced by slaughterhouses, because many components of this ABP category are as valuable as pure meat, which is why an in-depth analysis of types, quantities and processing possibilities of these by-products should be of special concern in corresponding studies (Sannik et al., 2013a, Sannik et al., 2013b).

The official requirements of the European Union do not follow the principle that ABP must be valued as fully as possible and to the maximum level. Prerequisite for that is the existence of a relevant monitoring system. Currently no official pressure exists on establishment of ABP monitoring in EU countries. Estonia also lacks any kind of system for ABP monitoring (excluding ABP registration of the first category in slaughterhouses) now. Therefore, at present, there is no overview available about the quantities of ABP categories that could be transformed into products via separate handling or into bioelectricity and heat via anaerobic fermentation.

At the same time from these enterprises where ABP is processed the data about the ABP quantities are not available or have the limited access (Sannik, 2010). An efficient monitoring system would make it possible to check and control the recourses of ABP in Estonia (Sannik et al., 2013a). The existence of a core calculation model for estimation of ABP quantities by categories and types will be the first step in monitoring system design.

Object of current study was the elaboration and evaluation the functionality of a calculation model for monitoring system, which makes it possible to assess the ABP resources in Estonian meat industry in cooperation with companies and state authorities.

METHODS

Calculations based on number of slaughtered animals (by species) and yield of ABP per animal during meat processing has been proposed. The following data from 2010 to 2012 were used.

1. Data from the existing databases, including the Commercial Register, the Ministry of Agriculture and the Estonian Institute of Economic Research. The Commercial Register provided data concerning the animal species and the number of animals processed in meat processing plants. The Ministry of Agriculture provided data concerning the number of live animals produced and sold to slaughterhouses by animal species during these years. The Estonian Institute of Economic Research provided data concerning the quantities of meat produced in Estonia during the same years by animal species, including data about imported meat and live animals. The Institute also provided data concerning the consumption of meat (including feed, forage, losses) and the export thereof (including live animals).

Table 1. Check-list for the monitoring provided in slaughterhouses

Row no.	Characteristics of slaughter-dressing	Data from slaughtering of cattle, pigs, sheep or poultry, kg
1	Average slaughter weight of carcass	DFS
2	Average live weight	DFS
3	**Meat and edible products**	**Sum of rows 4–5**
4	Meat and meat-products	DFS
5	**Edible products from slaughtering**	**Sum of rows 6–11**
6	Small fat, skirt, trimmings (edible)	DFS
7	Lungs, kidneys (edible)	DFS
8	Heart, liver (from poultry also crop, neck and partly legs)	DFS
9	Bones (edible)	DFS
10	Blood (edible)	DFS
11	Losses from slaughtering	DFS
12	**3rd category ABP**	**Sum of rows 13–23**
13	Leaf fat, omentum, fatty trimmings (inedible)	DFS
14	Lungs, heart, kidneys (inedible)	DFS
15	Blood (inedible)	DFS
16	Trachea, throat, esophagus	DFS
17	Stomachs and intestine (no cattle) cleaned	DFS
18	Bladder, genitals, spleens (no sheep), pig brains, hide-trims	DFS
19	Legs, horns/bristle/hoofs, feathers, partly poultry legs	DFS
20	Hides	DFS
21	Bones from cutting, chicken heads, partly pork heads	DFS
22	Vessels, tendons, cartilage, glands	DFS
23	Other ABP of the 3rd category	DFS
24	**2nd category ABP**	**Sum of rows 25–26**
25	Intestinal and stomachs content	DFS
26	Other ABP of the 2nd Category (perished animals etc.)	DFS
27	**1st category ABP**	**Sum of rows 28–31**
28	Cattle and sheep heads	DFS
29	Cattle and sheep spinal cord	DFS
30	Beef intestine (cleaned), intestine fat, sheep ileum	DFS
31	Sheep spleen	DFS
32	**Sum of ABP**	**Rows 12+24+27**

DFS - data from slaughterhouses.

2. A survey by means of pilot monitoring, on-site interviews and observations was conducted (Sannik 2010) in eight meat processing plants that produce approximately 75% of the ABP resources. The monitored plants and companies were the Rakvere Meat Processing Plant Ltd, Saaremaa Lihatööstus Llc, Rey Ltd, Linnamäe Lihatööstus Ltd, Aruküla Lihatööstus Llc, Märjamaa Lihatööstus Llc, Pandivere Lihatööstus Llc and Maag Lihatööstus Ltd. Electronic surveys were additionally conducted in four meat processing plants and companies: Atria Valga Lihatööstus Ltd, Otepää Lihatööstus Edgar Llc, Tallegg Ltd and Lihakarn Llc. The following data were collected from the meat processing plants and companies: a) the number of processed animals by species, b) the live weight and slaughter weight of the processed animals, c) the quantities of meat, meat products, slaughter sub-products and by-products by animal species, and d) the quantities of by-products

and waste by categories. Special form was worked out for conducting the monitoring (Table 1).

3. Data provided by the Estonian Animal Waste Processing Plant in Väike-Maarja (Vireen Ltd), which is the only plant in Estonia authorized to process animal by-products of 1st category (cf. Table 2). Data concerning ABP of the 1st category were collected by means of interviews and observations conducted in the course of repeated visits, and the accounting records of the company were also examined. Estimated ABP quantities were compared with the calculated ABP quantities of various risk categories generated in Estonian meat processing plants. The ABP yield percentages of the live weight were calculated by animal species on the basis of the quantities of meat, meat products, slaughter sub-products and by-products. For processing of collected data, an MS Excel database was created, which further was elaborated into calculation model for determination the quantities of ABP by types and categories. Using that calculation model, ABP quantities by categories and types were estimated and assessed for Estonian meat processing plants.

RESULTS AND DISCUSSION

From gathered data the average live and slaughter weight of the processed animals the quantities of meat, meat products, slaughter sub-products and other by-products were estimated, and the percentages of the outputs of the various ABP categories and types regarding live weight were calculated by animal species. These data were used for model calculation of ABP quantities by types and categories during given period and for a certain company (or region). The core of this model calculation for the year 2012 is presented in Table 2.

Based on model calculations, quantities of ABP generated in Estonian recognized slaughterhouses and meat processing plants in 2012 were the following: 21.8 thousand tons of ABP in total, of which 1.4 thousand tons constituted waste of the 1st category, 3.4 thousand tons were by-products of the 2nd category and 17.0 thousand tons (77% of the total volume of ABP) belonged to by-products of the 3rd category.

Monitoring carried out in 2012 revealed that most of animals were slaughtered in few larger production units. For example, 95% of the pigs utilized in Estonian meat processing plants were slaughtered in four slaughterhouses (Rakvere Meat Processing Plant, Atria Eesti Valga Production Unit and Saaremaa Lihatööstus) and 75–80% of the respective quantities of bovine animals were slaughtered in same three slaughterhouses. Also Estonian ABP derives mostly from these bigger representatives of the meat industry. Sheep were an exception – only 5% of the sheep farmed in Estonia were slaughtered in these plants that year. Table 3 presents an example of calculated ABP quantities generated in Estonian meat processing plants by risk categories according to proposed calculation model. An important enterprise considering ABP treatment is Vireen Ltd (Väike-Maarja Animal Waste Processing Plant). It processes (destroys) all animals that have perished on farms, ABP delivered by meat processing plants classified as waste of 1st category and other animal based materials (goods confiscated by customs, animals perished in traffic, zoos and for other reasons) etc.

Table 2. Average yield percentage and quantities (kg) of ABP from various types of animals slaughtered in Estonia in 2012 (per carcass).

Variable	Cattle		Pigs		Sheep		Poultry	
Average weight of carcass, kg	275		85		15		1,9	
Average live weight, kg	550		110		30		2,25	
	%	Qnt.	%	Qnt.	%	Qnt.	%	Qnt.
Meat and edible products	**42.97**	**239.23**	**80.20**	**88.23**	**36.15**	**10.78**	**78.89**	**1.78**
Meat and meat-products	40.75	224.10	66.83	73.51	34.80	10.44	75.64	1.70
Edible products from slaughtering	**2.22**	**15.13**	**13.38**	**14.72**	**-0.65**	**0.34**	**3.33**	**0.08**
Small fat, skirt, trimmings (edible)	2.12	11.66	1.95	2.14	0.00	0.00	0.00	0.00
Lungs, kidneys (edible)	0.13	0.70	2.19	2.41	0.00	0.00	0.00	0.00
Heart, liver (from poultry also crop, neck and partly legs)	0.36	1.97	0.26	0.29	0.63	0.19	3.33	0.08
Bones (edible)	0.01	2.94	9.98	10.98	0.00	0.00	0.00	0.00
Blood (edible)	1.61	8.86	2.00	2.20	0.72	0.22	0.00	0.00
Losses from slaughtering	-2.00	-11.00	-3.00	-3.30	-2.00	-0.07	0.00	0.00
3rd category ABP	**39.70**	**218.35**	**16.77**	**18.45**	**43.58**	**13.07**	**19.33**	**0.44**
Leaf fat, omentum, fatty trimmings (inedible)	4.19	23.02	1.17	1.29	2.70	0.81	0.00	0.00
Lungs, heart, kidneys (inedible)	0.77	4.21	0.54	0.59	1.43	0.43	0.00	0.00
Blood (inedible)	1.61	8.86	1.64	1.81	3.70	1.11	0.00	0.00
Trachea, throat, esophagus	0.70	3.85	0.62	0.68	1.04	0.31	0.00	0.00
Stomachs and intestine (no cattle) cleaned	3.00	16.50	3.77	4.15	5.37	1.61	0.67	0.02
Bladder, genitals, spleens (no sheep), pig brains, hide-trims	2.92	16.05	1.10	1.21	0.84	0.25	0.00	0.00
Legs, horns/bristle/hoofs, feathers, poultry legs (partly)	4.82	26.50	2.13	2.34	2.00	0.60	8.44	0.19
Hides	7.63	41.97	0.00	0.00	6.56	1.97	0.00	0.00
Bones from cutting, chicken heads, pork heads (partly)	10.68	58.75	3.33	3.66	16.50	4.95	3.11	0.07
Vessels, tendons, cartilage, glands	2.01	11.08	1.52	1.67	1.00	0.30	0.00	0.00
Others of ,the 3rd category ABP	1.37	7.56	0.95	1.05	2.43	0.73	7.11	0.16
2nd category ABP	**9.31**	**51.23**	**3.03**	**3.33**	**14.46**	**4.34**	**1.78**	**0.04**
Intestinal and stomachs content	8.93	49.13	2.93	3.22	14.26	4.28	0.00	0.00
Others of the 2nd category ABP (perished animals etc.)	0.38	2.10	0.10	0.11	0.20	0.06	1.78	0.04
1st category ABP	**8.02**	**44.13**	**0.00**	**0.00**	**5.81**	**1.74**	**0.00**	**0.00**
Cattle and sheep heads	3.00	16.50	0.00	0.00	4.73	1.42	0.00	0.00
Cattle and sheep spinal cord	0.02	0.13	0.00	0.00	0.08	0.02	0.00	0.00
Beef intestine (cleaned), intestine fat, sheep ileum	5.00	27.50	0.00	0.00	0.77	0.23	0.00	0.00
Sheep spleen	0.00	0.00	0.00	0.00	0.23	0.07	0.00	0.00
Sum of ABP	**57.04**	**313.70**	**19.80**	**21.78**	**63.85**	**19.16**	**21.11**	**0.48**

It should be emphasized that the technology of Vireen Ltd has been built upon the basis of the safety principles and designed for processing of the 1st category ABP only. Current study indicates that the average quantities processed by Vireen Ltd are approximately 10 thousand tons per year, which is the planned capacity of the plant also.

The yearly dynamics of the ABP quantities processed in Vireen Ltd is presented in Table 4. These data were used in ABP calculation model assessment for analyses of 1st category generation and reprocessing in Estonia.

Tabel 3. Quantities of ABP by risk-categories of major slaughterhouses and meat processing plants in Estonia in 2012

Variable	Cattle (x1,000)	Pigs (x1,000)	Sheep (x1,000)	Poultry (x1,000)	Total ABP (tons)
Slaughtered animals in the approved enterprises, thousands a year, incl.	**30.8**	**428.3**	**6.9**	**10,096**	
Rakvere Meat Processing Plant, tons	10	235	0	0	**7,336**
Atria Estonia, tons	8	110	0	0	**4,371**
Saaremaa Lihatööstus, tons	5	36	4	0	**2,092**
Others in total, tons	8	48	3	0	**3,182**
Tallegg, tons	0	0	0	10,096	**4,796**
3rd category ABP average quantities of a single animal, kg	176.38	16.64	11.11	0.44	
Rakvere Meat Processing Plant, tons	1,721.82	3901.64	0.00	0.00	5,623
Atria Estonia, tons	1,411.04	1,830.11	0.00	0.00	3,241
Saaremaa Lihatööstus, tons	846.62	598.94	44.42	0.00	1,490
Others in total, tons	1,411.04	798.59	32.21	0.00	2,242
Tallegg, tons	0.00	0.00	0.00	4,391.76	4,392
Total 3rd category ABP, tons in a year	**5,390.52**	**7,129.29**	**76.63**	**4,391.76**	17,048
2nd Category ABP average quantities of a single animal, kg	51.23	3.33	4.34	0.04	
Rakvere Meat Processing Plant, tons	500.09	781.97	0.00	0.00	1,282
Atria Estonia, tons	409.83	366.79	0.00	0.00	777
Saaremaa Lihatööstus, tons	245.90	120.04	17.35	0.00	383
Others in total, tons	409.83	160.06	12.58	0.00	582
Tallegg, tons	0.00	0.00	0.00	403.84	404
Total 2nd category ABP, tons in a year	**1,565.64**	**1,428.87**	**34.27**	**403.84**	3,428
1st category ABP average quantities of a single animal, kg	44.13	0.00	1.74	0.00	
Rakvere Meat Processing Plant, tons	**430.77**	**0.00**	**0.00**	**0.00**	431
Atria Estonia, tons	**353.02**	**0.00**	**0.00**	**0.00**	353
Saaremaa Lihatööstus, tons	**211.81**	**0.00**	**6.96**	**0.00**	219
Others in total, tons	**353.02**	**0.00**	**5.05**	**0.00**	358
Total 1st category ABP, tons in a year	**1,348.61**	**0.00**	**12.01**	**0.00**	1,361
Total ABP a year, tons	**8,364.76**	**8,558.15**	**122.91**	**4,791.60**	**21,838**

For example in 2012 the quantities of ABP delivered from meat industry to the reprocessing as 1st category was 4.9 thousand tons, which exceeded the predicted (by calculation model) amounts 3.5 times. Explanation to this contradiction is that great deal of other ABP categories were also sent for reprocessing as the most dangerous waste. Given example indicates to the insufficient use of 2nd and 3rd category ABP as raw material in Estonian meat industry. Thus, data about processed ABP in Vireen Ltd could be used for estimation of insufficient sorting of ABP into risk categories at meat processing plants.

Proposed monitoring system would become a powerful instrument for prediction of ABP daily (or for longer periods) quantities generated in meat processing plants by categories and types. Authors of current study did not found any reference in literature about up-to-date ABP monitoring systems set into praxis elsewhere. Therefore, Estonian system, if implemented, may become an example for ABP monitoring in other countries too. The existence of a monitoring system based on objective data should encourage meat processing plants to sort ABP into the various risk categories more thoroughly to allow treating these as valuable raw materials and to increase the added value of meat production chain accordingly. There is a large variety of applications for human and animal foods, rendered fat for cosmetics and chemistry products etc. Innovative proposals have been published concerning wider use of ABP proteins with better technological or nutritional properties for goods production (Toldra, 2012). At the same time it should be pointed out that regulatory requirements in many countries restrict broad use of ABP for food safety and quality reasons (Jayathilalan et al., 2012).

Tabel 4. ABP reprocessed in Vireen Ltd during 2006–2012 (tons yearly)

Year	2006	2007	2008	2009	2010	2011	2012
ABP purchased from meat-companies	4,388	4,424	4,532	3,551	3,630	4,320	4,888
Perished animals from farms	5,487	6,057	6,199	5,729	5,362	5,162	5,312
Other ABP	410	128	142	122	80	119	148
Total ABP	10,285	10,609	10,873	9,402	9,072	9,601	10,348

The following variables must be monitored and analyzed with sufficient frequency in order to ensure efficient processing of ABP with optimal economic impact:

1. The number of animals and poultry processed in slaughterhouses during a respective period (may base on existing datasets).
2. The division of animal carcasses processed in the same period on the basis of the SEUROP classification.
3. The quantities of raw materials of 3rd category ABP usable for human consumption (may be calculated with the appropriate prediction model).

The continuous monitoring would help to establish economically reasonable ABP processing in Estonia. The basic scheme of the initial monitoring system and the activities required for the introduction of it are presented on Fig. 1.

The database, into which the data about slaughtered animals will be gathered, forms the core part of the system. ABP quantities by various categories and types may be estimated using similar procedures given in the calculation model created during current research. The data will be accessible for ABP users via queries through computer networks and internet.

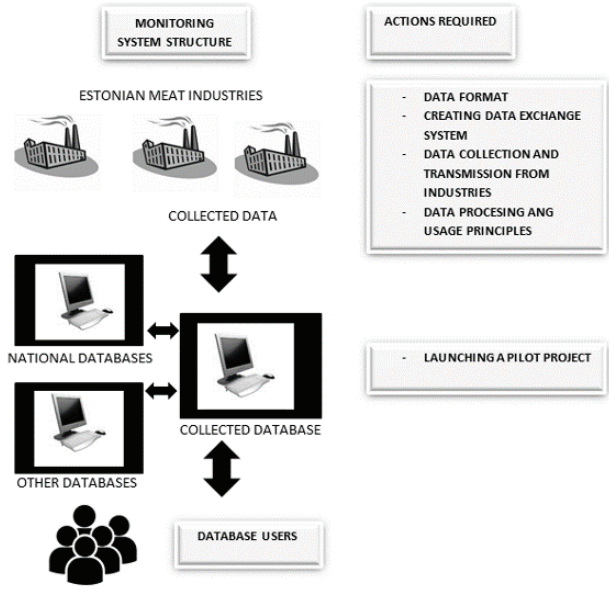

Figure 1. Principal scheme for creation of the proposed ABP monitoring system.

During the applied monitoring system elaboration, the following questions must also be answered:

- Who will administrate the system?
- How the system will be operated (entering, processing and analyzing the data)?
- What will be the reasonable intervals for the data entry?
- Who will have access to the data?
- Who and how will be involved in product development concerning ABP processing and producing information about the possibilities for the utilization various types of ABP in the most efficient way?

CONCLUSIONS AND SUGGESTIONS

Since there is no efficient monitoring system at present which makes it possible to control and manage the recourses of ABP in slaughterhouses and meat processing companies in Estonia, the relevant databases, procedures and methods should be worked out during the following studies. In development of the monitoring system, the simplicity, legal aspects, sufficient complexity and free access to required data must be taken into consideration.

Model presented in current research could be used as a base for ABP calculations. Official datasets of the Ministry of Agriculture of the Republic of Estonia, the Estonian Animal Recording Centre, the Estonian Veterinary and Food Laboratory, the Estonian Agricultural Registers and Information Board can be used as data sources for ABP estimation. Respective system for ensuring complex monitoring brings about legal issues and imposes a burden on the companies. Therefore, further activities should proceed from the principle that as little data as possible is to be gathered for monitoring from meat processing plants.

General plan for commercialization of ABP products should be worked out in which the aspects how to stimulate industries in ABP use for human consumption, pharmaceutic, cosmetic and other purposes. The mentioned commercialization plan should take into account the local and world markets demand and also give suggestions to all meat processors about the most optimal way in ABP sorting into several types and product-groups, and handling of these.

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