Food losses and waste in the poultry production chain: from farm to retail

Malher, X.[1*], Coudurier, B.[2] and Redlingshöfer, B.[3]

[1] LUNAM Université, Oniris, INRA, UMR1300 BioEpAR, CS 40706, F-44307 Nantes, France.
[2] INRA, CODIR, 147, rue de l'Université, F-75338 Paris Cedex 07, France.
[3] INRA, Mission d'anticipation Recherche/Société, 147 rue de l'Université, F-75338 Paris cedex 07, France.
***Corresponding author: xavier.malher@oniris-nantes.fr**

In the context of "2014 - European Year against Food Waste" and the EU project FUSIONS, a study has been conducted in a first attempt to define, describe and quantify food losses and waste from harvest to retail in various food supply chains in France. The present communication focuses on meat of Gallus species, i.e. meat of chicken and culled laying hens. In the present study, food losses were defined as product discard from human consumption due to sanitary reasons: mortality between harvesting and stunning and condemnation at slaughter house. Food waste was defined as any part of the animal which is edible or could, after processing, be eaten by humans yet which is used for other purposes, such as for pet food. The study drew in diagrams the different technical tracks from the live animal to the end product, with the various associated by-products coming out along the slaughter and processing lines, and their valorisation. Determinants for food losses and waste were found to be either technical, such as technical characteristics of processing tools, economical, such as the market demand side, regulatory or organizational, such as shelf management at retail with respect to products' expiry dates. Quantification of food losses and waste is difficult to perform due to the confidential character of business data. Issuing from the representation of the different slaughter and process steps, a calculation sheet has been implemented in order to estimate the share of food losses and waste according to various hypotheses, such as, e.g. percentage of carcasses devoted to cutting, or percentage of giblets valued for human consumption. The stages of marketing and retailing remained however poorly documented. This preliminary study needs to be discussed with a larger professional audience and challenged by further research on this topic of increasing public attention.

Key words: chicken, culled hen, meat, food losses & waste

Introduction

A reduction of food losses and waste is widely acknowledged as a means of meeting food system-related challenges such as global food security, global warming, preservation of natural resources and ecosystems, access to food for those in need, and hence of fostering food system sustainability (Nellemann *et al.*, 2009; Lundqvist *et al.*, 2008; Lipinsky *et al.* 2013). In the past years, the topic of food losses and waste, estimated to amount to one third of total food production (Gustavsson *et al.*, 2011) or one out of four calories produced (Lipinsky *et al.*, 2013), literally skyrocketed into the public space and has been put at the head of political and research agendas.

Literature on stating the problem and related environmental and economic impacts have become abundant, but reliable data on food losses and waste along supply chains remain scarce. Moreover, due to varying definitions, scope and data collection methods, they are often difficult to compare. Furthermore, research tends to repeatedly use a few gross estimates, notably from the 2011 FAO study (Gustavsson *et al.*, 2011) which covers the main agricultural production sectors in the main regions worldwide. Quantification initiatives at different scales (European, for example the EU-project FUSIONS[1]; international, e.g. the WRI/UNEP food loss & waste protocol[2]) have been launched to obtain harmonized data and to build a standardized quantification framework as reference.

This study on food losses and waste in Gallus meat supply chains is part of a much larger study conducted in 2014/2015 under the auspices of INRA, the French National Research Institute on Food, Farming and the Environment. As a partner of the EU-project FUSIONS, INRA has asked its permanent working groups on agricultural production sectors (seven animal and five plant production sectors) to respond, for their specific sector, to the following request:

- Discuss the concept of food losses and waste for application in their sector,
- Indicate the incidence and determinants of food losses and waste; identify their fate (waste management, recycling).
- Assemble available data in order to calculate food losses and waste quantities,
- Identify issues for research, knowledge on which to support food loss and waste prevention and reduction.

The scope of the study is food losses and waste at primary production, widely ignored so far in literature, and at succeeding operations up to distribution.

For the specific aim of quantification of food losses and waste at the up-stream stages of food supply chains, this study is expected to make a substantial contribution towards closing knowledge gaps, especially on the incidence of food losses and waste at farm level and at post-harvest stages.

The complete study will be published in the course of 2015.

Material and methods

DEFINITION AND SYSTEM BOUNDARIES

System boundaries of the studied supply chain are set to include the following stages: primary production, transport, slaughtering, cutting, packing and distribution. At primary production, food losses are considered from the moment on when the animal is ready to be slaughtered.

In the present study, meat is defined as the edible parts of the animal, i.e. the carcass and the giblets (heart, liver, gizzard). Blood cannot be considered as meat in poultry, because it cannot be collected by an appropriate mean, as it may be in slaughtered swines. Co-products are defined as anatomical elements derived from carcass which can be considered as edible but needs special processing before consumption, e.g. mechanically separated meat. By-products are defined as all parts that are excluded from human food: dead broilers (died during transport or euthanized), blood and non-edible parts of the animal (feathers, intestinal tract, feet, head) separated at slaughtering or at processing, and the carcasses or part of the carcass which have been withdrawn from the production line because of safety or technical reasons.

Definitions on food losses and waste vary. According to the Gustavsson *et al.* study to the FAO (2011), “food losses or waste are the masses of food lost or wasted in the part of food chains leading to ‘‘edible products going to human consumption.’’ Therefore, food that was originally meant for human consumption but which leaves the human food chain is considered food loss or waste even if it is then directed to a non-food use (feed, bioenergy, etc.)”. The FUSIONS-project retained a slightly different definition: Food that leaves the human food chain and is then used as animal feed or as bio-based material, is not considered food waste. Both the edible and inedible parts of food are considered.

[1] www.fusions-eu.org
[2] http://www.wri.org/our-work/project/food-loss-waste-protocol

For the purpose of this study, a different approach to the definition of food losses and waste has been adopted.

Food losses are defined as product discard from human consumption which mainly end up as two categories of by-products: C2 (destroyed) and C3 (may be used in animal feeding) for the following reasons:

- public health issues such as dead broilers, condemned carcasses (C2),
- technical reasons such as carcass defects (C3),
- regulatory reasons according to the process: when the chicken is marketed as cuts, the tail must be removed (C3), whereas the tail remains when the chicken is marketed as a ready-to-cook carcass .

Food waste was defined as discard of any part of the animal which is edible or could, after processing, be eaten by humans, due to:

- technological reasons, such as the characteristics of the on-line process (e.g. giblets discarded with abdominal package as by-products),
- economic reasons, such as lack of profitable demand from the market,
- regulatory or organizational reasons, such as shelf management at retail with respect to products' expiry dates,
- culinary traditions, such as for chicken feet which are not considered as edible in Europe in contrary to Asia,
- ethical reasons: e.g. spent hens may be euthanized in the poultry farm to avoid suffering from handling and transport to the slaughterhouse (Berg C., 2009).

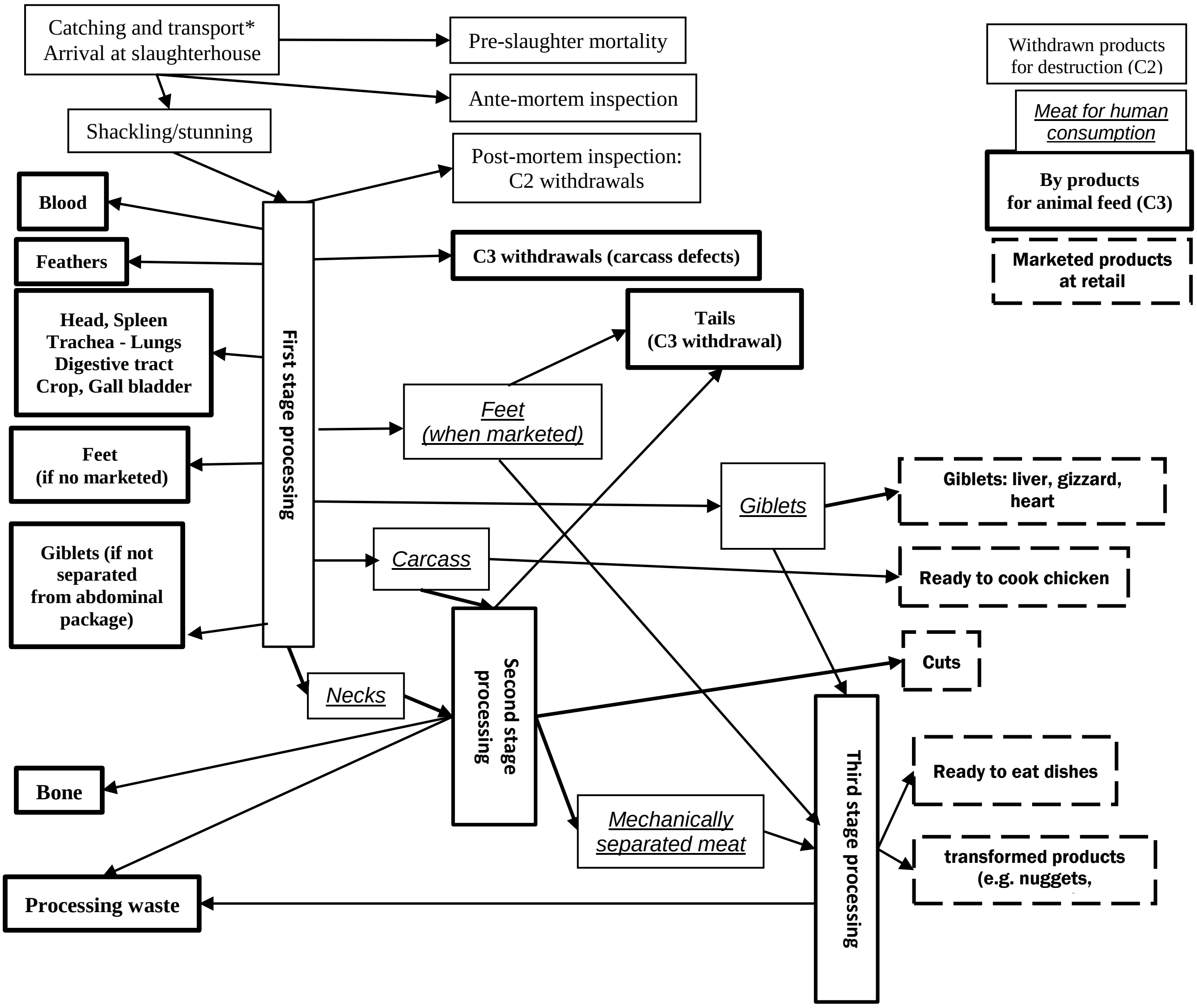
Data collection nevertheless covers also the amounts of inedible parts of the animal (animal by-products), and where possible the amounts of inedible parts valorized in different ways (pet food, energy, fertilizer etc.). Thus, the study provides comprehensive description of the slaughtering and process steps and quantifies shares and flows of animal and carcass fractions along the supply chain stages covered in the study.

MODELLING PATHWAYS FOR FOOD LOSSES AND WASTE IN BROILER MEAT

A diagram has been implemented (figure 1) to represent the various steps of broiler processing resulting in marketable products, with the 1st stage processing at the slaughterhouse (carcass and giblets), the 2nd stage processing, where cuts are obtained, and the 3rd stage transformation, where poultry products are combined with other ingredients to elaborated products or have to be processed to be edible (feet). From this diagram were identified the various steps, reasons and categories of discarded products in order to distinguish those which can be considered as food losses, respectively in C2 and C3 categories, and those which can be considered as food waste, according to whether technical or marketing reasons are at its origin (category 3).

Based on the representation diagram and a set of data giving the average yield of each part on an average live weight basis, a calculation sheet has been implemented in order to calculate, under various hypotheses, the weights of products and by-products in each category. For broiler, a data set was adapted from Domsen *et al.* (2004) (table 1) giving live weight decomposition into subparts. Data about culled laying hens are scarce. However, partial data from Gerder *et al.* (2009) are available: the dressing percentage was found to vary between 55% and 60 %, according to flocks, whereas the average percentage of fillet meat without skin and the average percentage of deboned leg meat without skin represented 11% and 14% respectively of the live weight of culled laying hens.

To achieve the calculation, the sheet has to be parameterized according to field data or hypothesis representing quantification of each step leading to food losses or waste. A simplified representation of the various steps where quantified parameters are needed is shown in figure 2. The simplification mainly consists in representing only one stage for inspection and withdrawal, whereas it could be conducted at different stages and with the condition that feet are not considered as edible. In the sheet, the parameters needed for food loss calculation are % of chicken dead during transport, % of chicken not correctly bled, % of chickens too small to be processed, % of C2 and C3 withdrawals. For waste calculation, the percentage of neck and giblets rejected from human consumption, the percentage of carcasses cut up and sold as ready-to-cook, the proportion of cutting by-products not used for 3rd level processing (e.g. mechanically separated meat).



*losses due to catching and transport are registered at arrival at the slaughterhouse

Figure 1: Representation of processing steps for broiler, from transport to processing into products, co-products and by-products

Table 1: Distribution of the average yield of each part of Ross broiler slaughtered at an average live weight of 1.9kg. Data adapted from Domsen *et al.* (2004).

Composition of live broiler	% of live weight
Feather and blood	7.38
Head	2.55
Feet	4.23
Internal package	6.15
Abdominal fat	1.59
Giblets *	4.36
Neck without skin	1.67
Neck skin	0.87
Miscellaneous	1.64
Carcass	69.56

Composition of broiler carcass	% of carcass weight
Wings	12.48
Breast skin	3,98
Shred meat	0,83
Fillet	27,42
Upper back	6,61
Legs	36,59
Lower back	6,54
Tail	0,91
Skeleton frame of the breast	4,64

* : Heart, liver, gizzard

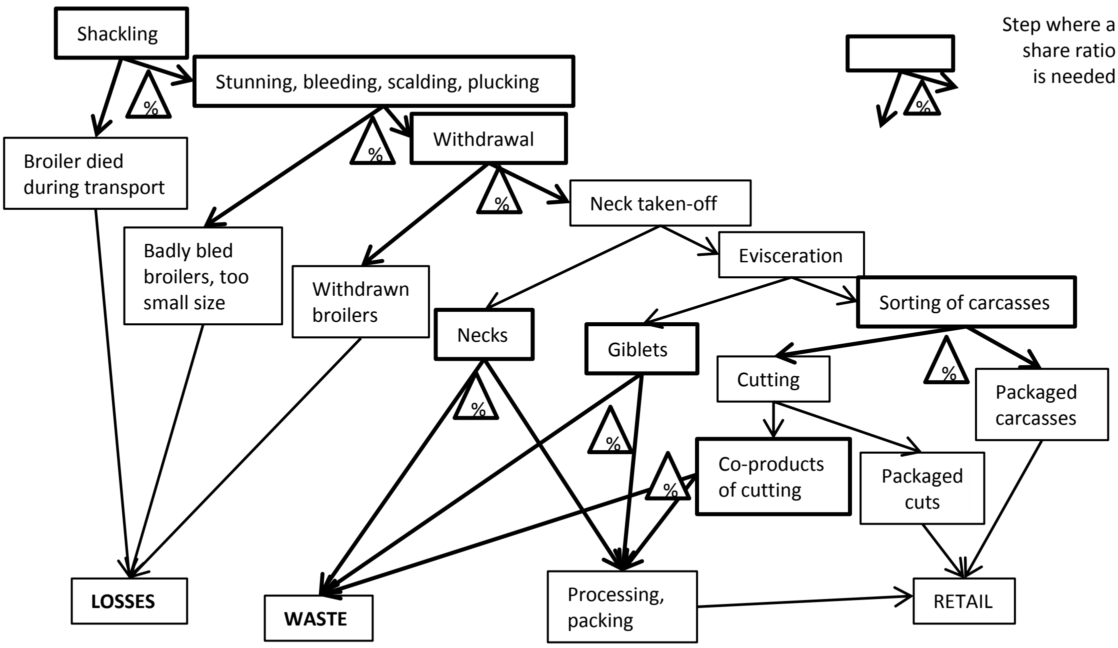


Figure 2: Simplified representation of the processing steps where a quantification of proportions is needed in order to achieve an estimation of the food losses and waste from harvest to marketable products.

The proportion of products and co-products may vary according to the cutting type commonly used in each country.

After packing, waste may be due to failure to sell the fresh products in due time. It may occur at two levels:

- at the processing plant level, when the production has not found clients within 3 or 5 days, according to the type of packaging technology,
- at retail level, before expiry date, i.e. within about one week.

This waste is difficult to investigate, because of the confidential character of such data, and its importance might largely vary among the various operators. Complementary to that, various strategies are implemented to avoid waste, especially through donations to charities.

Food losses and waste in chicken production

FOOD LOSSES

The importance of food losses is mainly dependent on the upstream sector, i.e. the conditions of harvest and transport (broken wings or legs (C3) or suffocation (C2)) and bird diseases at farm level (various withdrawal stages along the slaughter line, C2 or C3). Additionally, under or oversized broilers or struggling broilers may be insufficiently bled or be damaged at the first steps of the slaughter-line and are therefore discarded (C3 food losses).

Food losses consecutive to harvest mainly consist in fractures, hematoma, bruises. Their incidences are not so well documented than in spent hens (see further) but are variable in relation with the organization of the harvest and the number of harvesters in the barn. A survey among 46 poultry slaughterhouses in France (Dusanter *et al*., 2003) showed that the harvest of 20 000 standard broilers in a barn of 1000 m^2 by 9 harvesters lasted 3h15, whereas the harvest of 4400 free-range broilers (Label-Rouge) in a 400 m^2 by 7 harvesters lasted 2h45. To limit the consequences of too harsh conditions, an automatic harvest machine could be used, but it can result into unequal distribution into the transport crates, with higher mortality in overcrowded crates.

Depending on transport conditions (crate density, duration and climatic conditions of transport, duration of resting at slaughterhouse before shackling), mortality rates vary widely. As example, in French conditions (Le Bouquin *et al*., 2010) the mortality rate was 0.18% (CI 95%: 0.14-0.21) in 403 batches from 17 slaughterhouses after an average transport duration of 2h46 (0h35-7h30) and an average waiting time of 3h45 (0h05 – 12h55). Other studies in different other countries give similar results:

0.12% in Great-Britain (Haslam *et al*., 2008), 0.25% in Czech Republic (Verecek *et al*., 2006), 0.35% in Italy (Pettracci *et al*., 2006), 0.46% in the Netherlands (Nijdam *et al*., 2004).

Withdrawals are made at the inspection point or along the slaughter line, either for safety reasons (lesions caused by disease) or for visual defects (post bleeding damage by machine, for example). Some withdrawals are only partial, according to the kind and extent of the lesions. Then, the carcasses are directed to the cutting plant for withdrawal of the damaged part. In a review of studies previous to 2007, with differences between calculation methods, size of the sample, season of measurement, Lupo (2010) reported variations around a median of 1.2%. In the two main area of poultry production in France (Bretagne and Pays-de la Loire), the annual reporting of the technical results of standard broiler batches indicates an average withdrawal rate of 0.68%, 0.89%, 1.06% and 1.16% for 2010, 2011, 2012 and 2013 respectively (ITAVI, 2014). But several uncertainties remain: whether it is a % of individuals or a weight %, whether it is corrected for partial withdrawals and whether the total weight was obtained before or after chilling.

FOOD WASTE

At the slaughterhouse level, food waste of broiler meat results from a technical inadequacy of the tool to valorize every edible part in the broiler, e.g., when a tool for the mechanical separation of meat is lacking. It can also be related to a processing cost too high to allow for commercialization, and possibly to competition with the pet-food market.

A special issue is the status of broiler feet. Until a recent period they were considered as by-product, therefore their discard was not considered as food loss or waste. But today, due to the growth of export markets, this by-product is considered as edible after preparation. This new commercial outlet requires a special inspection, to withdraw abnormal feet, mainly due to lesions of footpad dermatitis, and, therefore, creates a new kind of food loss at the transformation plant level. When processing tools for the feet at the plant level are lacking, the question is: should the discard of feet be considered as a food waste? These two conditions should be considered. Moreover, as the rate of footpad dermatitis is especially high in standard broiler, this commercial outlet motivates furthermore a better control of this disease which impairs the welfare of the broilers.

The calculation sheet has been used for quantification of food losses and waste. Variations in percentage of mortality during transport and % of withdrawal at the slaughterhouse directly impact the level of food losses, as well as variations in the rate of discarding co-products (giblets, necks, cutting waste) will impact the level of food waste.

Indirectly, the percentage of carcasses processed into cuts and the use of feet for food changes the volume of food losses and waste. A reference situation (table 2) was built on the following hypotheses: withdrawal of 1.40 % of chicken (dead, undersized, safety or technical reasons), discard of 30% of co-products (giblets, necks, cutting waste) and cutting of 60% of the available carcasses.

Table 2: Distribution of live weight between total food losses, waste, other by-products and products and variations induced by two scenarios: (i) feet are considered as co-product but 80% are withdrawn because of foot dermatitis and (ii) 40% of the carcasses are processed in cutting plants instead of 60%.

	Reference* (%)	Feet as co-product	40% of carcasses further processed
Total food losses	**1,40**	+ 238,6%	0,0%
Other by products	**25,49**	-16,4%	-3,0%
Food waste	**4,26**	0,0%	-17,4%
Products for retail	**68,85**	+ 1,2%	+ 2,2%

* 1.4 % of broilers are withdrawn at the beginning of the process (dead, undersized, safety or technical reasons), 60% of carcasses are processed in cutting plants, 30% of co-products (giblets, neck, waste of cutting) are discarded (waste).

This situation was compared to two other scenarios: one where feet are directed to human consumption and one where only 40 % of the carcasses are processed. The main variation in the first scenario is related to the feet, which represent about 4 % of the total live weight, and go from the category of by-products mainly into the category of food losses due to a high level of pododermitis whereas a little proportion is converted into co-product for human consumption. The second scenario illustrates the fact that the whole carcass is considered as completely edible at retail whereas the preparation and the consumption of this carcass at home will most probably results in a variable proportion of waste.

In the slaughterhouses and processing plants, the fresh products must find an outlet within 4 days after packing to keep a sufficiently long shelf-life (about 8 days). After this deadline, products must find an alternative outlet either into other transformation processes (cooking processes, ready-to-eat dishes, canning…) giving a longer lifetime but at lower market value, or be given to charity organization or to pet-food companies. The volumes here are difficult to know, each company having its own practices in order to manage this point to its best interest.

As previously mentioned, reduction of waste at retail level is mainly linked to shelf management with respect to products' expiry dates and each retailer has his own strategy to cope with this constraint. On this point, management of poultry products do not differ specifically from other fresh products and no specific data are available. The French Retail and Trade Federation gives an overall estimation of 5 to 6 % of unsold products that may be directed either to charity organization or to destruction.

USES OF BY-PRODUCTS

The fate of by-products and discards resulting from processing is also of interest when it comes to the debate on how to avoid waste of valuable animal protein and fat. The French Union of By-Products Industry (SIFCO) reported that 718 500 tons of raw material from by-products of poultry origin were treated by its members in 2013. Processed poultry protein was used by the pet-food industry at 99%, whereas poultry fat was used by the pet-food industry at 46%, in aquaculture at 12% and in other animal feed at 35%.

Food losses and waste in spent layers and breeders

Culled birds from flocks of layer hens and breeders are considered as a co-product of the production of table and hatching eggs. They represented only 5.5% of the total production of Gallus meat in France in 2013 (Ministry of Agriculture). Due to its low quality compared to chicken, this meat is of poor economic value, e.g. paid between 0.19 and 0.33 €/kg in France in 2012 (ITAVI 2013) while cost of collection and transport was reported to be between 0.07 and 0.08 €/kg (Chambre d'Agriculture des Pays de la Loire, 2013). For ethical reasons (fractures induced by manipulation and suffering during transport), on-farm killing of the birds is practiced in some countries such as in Sweden or Switzerland. The rate of bone fractures due to catching at depopulation showed high levels as reviewed by Kristensen *et al.* (2001), but varying in a ratio from 1 to 5 according to surveys, with highest level of 24% (Gregory et Wilkins, 1989). More recent studies, using more animal friendly catching methods (each hen being caught by the two legs) showed rate of 4.6% instead of 13.8% and 10.1% when caught by one leg, individually or in group of 3 respectively (Knowles, 1994).

Average mortality rate during transport was reported to be 0.27% in Great-Britain (Weeks *et al.*, 2012), 1.22% in Italy (Petracci *et al*., 2006), with higher risk either in lower or higher temperature. Distance is also known to be a risk-factor. In France, the average distance between laying hen farms and slaughterhouses was found to be 276 km in a survey in 2013 (Chambre d'agriculture des Pays de la Loire) and 600 km for breeders. Interviewed professionals mentioned that the mortality rate could be exceptionally as high as 20%.

Slaughtering and processing of spent hens request special equipment. Moreover, the heterogeneity of their size makes automation of cutting impossible, the presence of eggs in the oviduct makes evisceration more difficult and giblets are not taken off from the internal package. Specific processing consists in boiling the carcasses in order to obtain shredded meat for use in other processed products (Gregory and Wilkins, 1989). The slaughter yield of spent hens is about 57%, with a variation between 55% and 63%, according to authors and samples i.e. about 12% lower than in broilers, with a poorer percentage of fillet, i.e. between 14 to 20% of the carcass weight (Ristic *et al.*, 2006; Guerder *et al.*, 2009). According to interviewed professionals, about 70% of the carcass is used for human consumption, whereas 30% becomes processed animal protein.

For all these reasons, food losses and waste related to spent hens and breeders are much more important in percentage of live weight than in broiler production. This situation varies largely among countries. In Sweden, where 5.5 millions of hens are culled yearly, 50% are directed to human consumption, 30% become processed animal protein and are exported for mink feed and 20% are incinerated (www.svt.se, www.supermiljobloggen.se). In Switzerland, GalloCircle, an egg producer organization, has been encouraging the slaughtering of spent hens for human consumption: in 2008, only 22% of the hens went to human consumption (soup hen), whereas in 2012, 30% went to soup hen production and 45% to shredded meat. In France, all spent hens and breeders are slaughtered in a slaughter house, except in case of stamping out for sanitary reasons. In 2012-2013, about 1/3 of the birds were exported alive to slaughter plants in neighboring countries, while 2/3 were being processed in France at equal share into ready-to-cook hens and cuttings. Roughly, about 70% of the products were exported frozen to developing countries, 10% were exported mainly frozen to EU countries, 10% were marketed in France as fresh meat, mainly as ready-to-cook hens, and 10%, mainly cuttings, were marketed to French processing plants.

Perspectives

Our study on food losses and waste describes qualitatively and quantitatively the different steps and processes that broilers and hens undergo between farm to distribution and analyzes how and why it comes that edible parts are finally not consumed. From this overview in the *gallus* meat supply chain, we can suggest 5 general issues to be discussed for a reduction of food losses and waste:

1- Food losses are, on the one hand, mainly consecutive to animal health and welfare problems but also, on the other hand, conditioned by food safety and quality control measures. Therefore losses can be lowered by improvement of animal health and welfare but, conversely, could be increased if more strict food safety and quality control standards should be implemented.

2- The definition of edible parts might change the volume of waste according to the point of view used, as illustrated by the example of the feet. Depending on the cultural background, some parts qualified as by-products by the European regulation might be considered as edible co-products in other societies, therefore could be considered as waste when not consumed.

3- Cutting operations on a carcass produce, *per se*, by-products which are accounted for meat when the carcass is sold as "ready to cook" at retail. On the other hand, technology in cutting plants has soon reduced the technical waste by finding new uses for them, as illustrated by the mechanically separated meat technology and the preparation of ready to eat dishes and of new products.

4- Conflicting ethical positions arise between animal welfare and food waste concerns, as illustrated by the dilemma between on-farm killing of spent hens and slaughtering them for the meat supply chain. Another conflict arises between the opposition of consumers to feed live-stock with processed animal protein by-products, and the demand for recycling of this available animal protein and fat, which induces a need for other sources of plant or animal proteins for animal feed.

5- Whatever the level of food losses and technical waste along the processing chain, there is a final stage where quantification of waste is difficult to investigate, that is the proportion of products which do not find a market at the end of the chain as well as the proportion of products unsold at retail which are destroyed, even if a limited quantity finally are donated to charity organizations. To optimize even more the marketing of fresh products, new technologies (for example packaging, physical or biological treatment) can contribute to a significant extension of products' shelf life and innovation in the agro-industry can help finding new outlets for co-products. Furthermore, more collaboration by information exchange between the food industry and distribution can enable better matching of supply and demand.

References

BERG, C. (2009) On farm-killing of poultry for disease control and other emergencies, Proceedings of the Nordic Poultry Conference, Reykjavik, Nov 17th-20th 2009, 4pp, http://fr.slideshare.net/charmkey5/lotta-berg-2009-on-farm-killing-poultry-nordic-poultry-conf.

BOUVAREL, I., LAURAS, B., DROUIN, P. and HIBAL, N. (1996) Nature et importance des défauts d'aspects des carcasses de dindes. Conditions d'élevage susceptibles d'intervenir sur les lésions de picage et de griffage. *Sciences et techniques avicoles*, 16, 36-45.

CHENUT, R. (2013) Performance technique et coûts de production en volailles de chair, poulettes et poules pondeuses. Document ITAVI, 61 pages.

DOMSEN, D., CAPELLE, A., and TRAMPER, J. (2004) Food yield analysis in the poultry processing industry, *J of Food Engin.*, **65**, 479-487

DUSANTER, A., BOUVAREL I. and MIRABITO L. (2003) Enquête sur les conditions de ramassage et de transport des volailles prêtes à abattre en France. *Science et Techniques Avicoles*, **43**, 4-14.

FEDERATION DES INDUSTRIES AVICOLES (2012) Guide de bonnes pratiques de collecte des pattes de poulet destinées à la transformation pour l'alimentation humaine, 12 pp.

GREGORY, NG, and WILKINS, L.J. (1989) Broken bones in domestic fowl – Handling and processing damage in end-of-lay battery hens. *British Poultry Science*, 30 (3), 555-562.

GUERDER, F., PARAFITA, E., DEBUT, M. and VIALTER, S. (2009) Première approche de la caractérisation de la qualité technologique de la viande de poule. *TeMA – Techniques et Marchés Avicoles* (9), 8-13.

GUSTAVSSON J., CEDERBERG J., SONESSON J., VAN OTTERDIJK J. and MEYBECK A., (2011) Global food losses and food waste: extent, causes and prevention. FAO, Rome, 29pp.

HASLAM, S.M., KNOWLES, T.G., BROWN, S.N., WILKINS, L.J., KESTIN, S.C., WARRIS, P.D. **and NICOL, C.J.** (2008) Prevalence and factors associated with it, of birds dead on arrival, at the slaughterhouse and other rejection conditions in broiler chickens. *British Poultry Science*, **49**, 685-696.

KNOWLES, T.G. (1994), Handling and transport of spent hens. *Worlds Poultry Science*, 50 (1), 60-61

KRISTENSEN, H.H., BERRY, P.S. and TINKER, D.B. (2001) Depopulation systems for spent hens - A preliminary evaluation in the United Kingdom, *Journal of Applied Poultry Research*, 10 (2), 172-177

LE BOUQUIN, S., HILLION, S., ALLAIN, V., BALAINE, L, PETETIN, I., PERASTE, J., MICHEL, V., LUPO, C. and CHAUVIN, C. (2010) Prévalence et facteurs de risque de mortalité des volailles de chair au cours du transport vers l'abattoir. TeMA - *Techniques et Marchés Avicoles* 2010 (5), 4-11.

LIPINSKI, B., HANSON, C., LOMAX, J., KITINOJA, L., WAITE, R. and SEARCHINGER, T. (2013). "Reducing Food Loss and Waste." Working Paper, Installment 2 of Creating a Sustainable Food Future. Washington, DC: World Resources Institute.

LUNDQVIST J., DE FRAITURE C. and MOLDEN D. (2008) Saving water: from field to fork. Curbing losses and wastage in the food chain. Stockholm International Water Institute (SIWI). 36p.

LUPO, C. (2010) Appréciation du risque de saisie sanitaire des carcasses de volailles à l'abattoir à partir d'informations sur la chaîne alimentaire, Thèse de l'Université de Rennes1. 320 pp.

LUPO, C., CHAUVIN, C., BALAINE, L., PETETIN, I., PERASTE, J. and LE BOUQUIN, S. (2007) Saisie sanitaire lors de l'inspection des poulets de chair à l'abattoir : état des lieux dans le grand Ouest de la France. *Recueil des communications des 7èmes Journées de la Recherche Avicole,* Tours, 28-29 mars 2007, 501-504.

NELLEMANN, C., MACDEVETTE, M., MANDERS, T., EICKHOUT, B., SVIHUS, B., PRINS, A. G. and KALTENBORN, B. P. (2009). The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment.United Nations Environment Programme, GRID-Arendal,www.grida.no, w*ww.grida.no/files/publications/FoodCrisis_lores.pdf*

PETRACCI, M., BIANCHI, M., CAVANI, C., GASPARI, P. and LAVAZZA, A. (2006) Pre-slaughter mortality in broiler chickens, turkeys, and spent hens under commercial slaughtering, *Poultry Science*, **85:** 1660-1664.

RISTIC, M., WERNER, R., BITTERMANN, A., SCHUESSLER, G. and ERHARDT, S. (2006) Carcass value and meat quality of soup hens - influence of hen management. *Mitteilungsblatt der Fleischforschung Kulmbach*, **45** (17), 9-14

SCISLOWSKI, V., LAPASIN, C., PONCHANT, P., GUARDIA, S., NASSY, G. and CHEVILLON, P. (2012) Recherche de méthode d'évaluation de l'expression de l'empreinte carbone du produit viande, *Institut de l'Elevage*, Compte-rendu final 00 12 33 023, Annexe 1, 105-108.

SIFCO, 2014. *Rapport d'activité* SIFCO 2013, 44 pp.

VECEREK, K., GRBALOVA, S., VOSLAROVA, E., JANACKOVA, B. and MALENA, M. (2006) Effects of travel distance and the season of the year on death rates of broilers transported to poultry processing plants. *Poultry Science*, **85**, 1881-1884.

VOSLAROVA, E., JANACKOVA, B., VITULA, F., KOZACK, A. and VECEREK, V. (2007) Effects of transport distance and the season of the year on death rates among hens and roosters in transport to poultry processing plants in the Czech Republic in the period from 1997 to 2004. *Veterina Medicina*, **52**, 262-266.

WARRIS, P.D., BEVIS, E.A., BROWN, S.N. and EDWARDS, J.E. (1992) Longer journeys to processing plants are associated with higher mortality in broiler chickens. *British Poultry Science*, **33**, 201-206.

WEEKS, C.A., BROWN, S.N., RICHARDS, G.J., WILKINS, L.J. and KNOWLES, T.G. (2012) Levels of mortality in hens by end of lay on farm and in transit to slaughter in Great Britain. *Veterinary Record*, 170 (25), 647-650.