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Analysis of losses and edible and inedible by-products generated during harvesting, slaughtering and processing stages of broiler chickens under industrial conditions

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Food losses, as major sustainability obstacles, have raised enormous concerns in recent years due to their contribution not only to significant resource, climate, and environmental impacts but also to huge economic and nutritional impacts. While various studies have indicated that reducing food loss and waste could benefit food security and environmental sustainability, the extent of such benefits depends on the level of reduction and thus requires a good benchmark of the current loss and waste throughout the agri-food supply chain. Food losses occur at various points in the poultry supply chain, from production and harvest to distribution and consumption. A large proportion of unintentional food losses occurs during the *ante-mortem* phases. At the end of the growing phase, birds are caught, loaded into cages or coops, and transported to a processing plant that may be located either close to or far from the farm. Many problems may occur at these stages that potentially increase the rate of mortality, liveweight losses, and carcass downgrading. Before birds are caught and crated, feed is removed to allow time for the evacuation of intestinal contents. This reduces the incidence of faecal contamination of the carcass, which may occur during slaughtering. However, the length of fasting is important because it affects liveweight losses, which can impair carcass weight and yield. In the first 4–6 hours, weight loss in birds is mainly due to emptying of the gut, so carcass yield is not negatively influenced. After 6 hours, there are also losses in moisture and nutrients from body tissues, which reduce carcass weight and yield. During catching and crating operations, a certain level of trauma, such as haemorrhages, bruises, and broken bones, occurs and originates food losses at the slaughter plant, as these parts must be trimmed and discarded as by-products, and the remaining parts are downgraded and used as raw materials for further processing. In addition, trauma occurring during harvesting at the farm exacerbates pre-slaughter mortality. Indeed, birds that are dead on arrival (DOA) at the plant represent a complete loss of economic value. The birds may be exposed to a variety of potential stressors during transit, including the thermal demands of the transport microenvironment, acceleration, vibration, motion, impacts, fasting, withdrawal of water, social disruption, and noise. These factors cause adverse effects on the birds that may range from mild discomfort to death. Environmental conditions during transport and lairage of poultry have also been shown to affect live shrink and processing yield, especially because birds respond to the increased temperature by increasing panting, which alters water intake and body moisture loss profiles. At the time of slaughter, a certain percentage of broiler carcasses and parts are condemned by veterinary inspectors due to signs of pre-existing disease, severe injury, abnormality, or contamination, making the products unfit for human consumption. In addition, huge amounts of edible and inedible residuals that possess great potential for exploitation in both food and non-food fields are generated during poultry slaughtering and processing. In the poultry sector, nowadays abattoirs are mostly

associated with specialized meat processing factories, following increased demand for ready-to-cook and ready-to-eat products. For example, the processing line in broiler abattoirs has increased fourfold during the last decades, resulting in an improved processing capacity within the same factory for a single line, from 4.5 (in 1970) to 36 tons of meat per hour. Following this trend, the poultry industry has developed effective processing strategies to turn nearly all edible and inedible by-products into something marketable. Non-edible items have been utilized by specialized facilities to produce processed animal proteins for pet food, feed, and fertilizers, as well as fats and oils for feed, oleochemical industries, soap industries, and the biodiesel sector. However, progressive centralization and increased capacity of slaughter plants have made the production of by-products more concentrated, while the size of collection points is usually limited, and the mass and variety resulting from poultry slaughtering and meat processing operations are constantly increasing. In addition, the greater availability of synthetic alternatives (i.e., plastic fibers, chemical fertilizers, etc.) has progressively decreased the value of animal inedible by-products. In most cases, the reference markets and the demand for primary products (e.g., carcasses, cuts, processed products) and edible by-products (e.g., organs) are highly diversified depending on the place of production. The increasingly stringent food safety requirements, potential high costs of storage and transportation, and the need to minimize processing times often make it economically convenient to divert the use of edible by-products for purposes other than food production. Indeed, demand for non-carcass components and low-value meat cuts has tended to substantially drop as increased incomes make high-value meat and meat products more affordable. Nowadays, the majority of them are either exported to low-income countries or used as raw materials for manufacturing emulsified-type processed products (e.g., frankfurter-type sausages, nuggets), as well as for the same non-food purposes adopted for non-edible items. A paradigmatic example of the quick evolution of the concept of by-product is represented by “mechanically separated meat.” The increasing availability of by-products from meat processing has favoured the development and adoption of technologies capable of recovering edible materials from carcass residues, trimmings, and low-value parts. The mechanical separation of flesh adhering to the bones was first introduced by fish processors before World War II and later adopted by the poultry industry to recover meat from low-value cuts (i.e., neck, back) remaining after removal of the breast, legs, and wings. In the 1970s, mechanically separated meat derived from irregularly shaped bovine and pig bones also became quite common. The adoption of this recovery technology is very effective for reducing the potential waste of high-protein supplies, and the resulting paste-like materials are widely used, especially in the formulation of emulsion-type sausages. However, because of changes in consumer perception, in some countries mechanically separated meat is increasingly considered a low-quality edible material, and currently, there is a risk of its potential downgrading to an inedible product. Rational management and utilization of primary products and by-products are not only necessary for protecting consumers’ interests and reducing environmental impact but are also of great significance for the sustainable development of the modern meat industry in the current challenging context. Indeed, the evolution and specialization of the demand for products of animal origin make the rational exploitation of the raw materials originating from poultry slaughtering and meat processing increasingly complex. In addition, the growing diffusion of processed products ready for

consumption is dramatically increasing the proportion and concentration of potential by-products generated during industrial processing, which in the past were directly managed by end-users. Therefore, the implementation of planning and management strategies, as well as sustainable improvements in the production and efficient use of by-products, have become key tasks for the poultry industry. Acknowledgements: This work has been partially supported by the DESTINY Horizon Europe Marie Skłodowska-Curie-2022-DN Marie Skłodowska-Curie Action project “Design and Sustainability Assessment of Innovative biomass production systems and value-chains in the Bioeconomy - DESTINY” (G.A. n. 101119940).

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