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Review

Potential of chicken by-products as sources of useful biological resources

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ABSTRACT

By-products from different animal sources are currently being utilised for beneficial purposes. Chicken processing plants all over the world generate large amount of solid by-products in form of heads, legs, bones, viscera and feather. These wastes are often processed into livestock feed, fertilizers and pet foods or totally discarded. Inappropriate disposal of these wastes causes environmental pollution, diseases and loss of useful biological resources like protein, enzymes and lipids. Utilisation methods that make use of these biological components for producing value added products rather than the direct use of the actual waste material might be another viable option for dealing with these wastes. This line of thought has consequently led to researches on these wastes as sources of protein hydrolysates, enzymes and polyunsaturated fatty acids. Due to the multi-applications of protein hydrolysates in various branches of science and industry, and the large body of literature reporting the conversion of animal wastes to hydrolysates, a large section of this review was devoted to this subject. Thus, this review reports the known functional and bioactive properties of hydrolysates derived from chicken by-products as well their utilisation as source of peptone in microbiological media. Methods of producing these hydrolysates including their microbiological safety are discussed. Based on the few references available in the literature, the potential of some chicken by-product as sources of proteases and polyunsaturated fatty acids are pointed out along with some other future applications.

1. Introduction

The production and consumption of poultry products have been on the increase globally. Statistics from poultry industry watchers showed that United States, China and Brazil maintain their lead as the biggest producers of poultry meat. Each is expected to produce up to 19,852, 18,102 and 12,200 thousand metric tons of poultry meat, respectively, in 2011 (USDA, 2011a). However, China and Brazil top the list in the production of chicken meat, each having a forecast of 13,000 and 11,750 thousand metric tons, respectively, in 2011 (USDA, 2011b). With this large production, thousands of tons of organic by-products in the form of viscera, feet, head, bones, blood and feathers are generated (Zhu et al., 2010). The viscera constitute about 30% of these wastes while feather could be up to 10% (Jamdar and Harikumar, 2005; Grazziotin et al., 2007).

In the past, it was a common practice to convert animal wastes into livestock feed and organic fertilizers. As a result, processes such as rendering, composting, chemical, microbial and thermal treatment of poultry and other animal wastes were developed and widely researched (Salminen and Rintala, 2002; Cai et al., 1995; Korniłłowicz-Kowalska and Bohacz, 2011). In addition, waste management methods such as dumping, landfilling and incineration are also practiced in different parts of the world (Salminen and Rintala, 2002). However, after the outbreak of the Bovine Spongiform Encephalopathy (BSE) in the United Kingdom, United States and some countries in Europe coupled with the link established between consumption of BSE infected meat and the development of Creutzfeldt-Jakob disease, there has been a sharp decline in the conversion of animal by-products to feed and certain legislations in some countries disallow indiscriminate dumping or landfilling of animal wastes. Composting and anaerobic digestion which are considered as better options for converting biological wastes to value added products still possess certain drawbacks which are hindering their upscale. Hence, researches on alternative methods of processing animal wastes to useful products are still ongoing in different parts of the world. One such alternative involves development of techniques for recovering biological compounds from animal wastes which are later use for some downstream processing or application. Since animal wastes are composed of biodegradable C, N, H, O and S compounds, these compounds can be recovered and utilised in different industries while also helping to reduce volume of the starting waste product.

Thus, a large number of studies on chicken and other animal by-products have focused on extraction, isolation and utilisation of the biomolecules that are trapped inside these products. Specifically,

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different chicken by-products are known to contain appreciable amount of biomolecules like proteins, enzymes and lipids (Ockerman and Hansen, 2000; Raju et al., 1997). These biomolecules can be recovered and processed into products which can be useful in microbiology, medicine, pharmaceuticals, human nutrition and cosmetics (Bueno-Solano et al., 2009). To this end, some attempts have been made to test the suitability of different chicken by-products for the production of specific value added products such as protein hydrolysates, enzymes and polyunsaturated fatty acids (Kim et al., 2001; Grazziotin et al., 2007; Surówka and Fik, 1994; Rathina Raj and Mahendrakar, 2010; Patil and Nag, 2011). However, there is so far a lack of publications addressing in a comprehensive manner the subject matter of recovery and utilisation of organic biomolecules from chicken by-products.

Thus, this review discussed the utilisation of poultry by-products as sources of protein hydrolysates, enzymes and polyunsaturated fatty acids. Due to the diverse applications of protein hydrolysates in different fields and industry coupled with the sizable number of literature references available on utilisation of chicken by-products as substrates for producing protein hydrolysates, a large section of this review covers the functional and bioactive properties of these hydrolysates, their usage as sources of peptone, methods of production as well as their microbiological safety. Based on the few literature references available, methods of deriving industrial proteases and polyunsaturated fatty acids (PUFAs) from chicken wastes were reviewed along with some future applications.

2. Animal by-products: processing methods and utilisation

The Commission of the European Communities Regulation (EC) No. 1096/2009 defines animal by-products as, whole body of an animal, parts from the body of an animal or products derived from animals which are not meant for human consumption (European Commission, 2009). These by-products are grouped into three categories based on their level of risk for transmitting pathogens and toxic substances. The third category which comprises animal by-products such as feather, skin, hides, blood, heads, feet, horn and hoof obtained from healthy animals are permitted to be used for certain beneficial purposes (Table 1) while those in category 1 are expected to be buried or incinerated at designated sites and by approved agency (Barrena et al., 2009). Animal by-products classified as category 2 are also considered as high risk products but can be used as feedstock for composting, biogas generation and energy production after pretreatment at high temperature and pressure. These regulations have consequently led to some modification of the conventional methods of processing and utilisation of these wastes while also creating an opportunity to search for novel waste processing and utilisation methods.

Table 1
Methods of utilising chicken by-products and their corresponding categories according to the EU legislation.

Uses of chicken by-products	EU classification of the by-products[a]
Livestock feed	Category 3
Pet food	Category 3
Aqua feed	Category 3
Cosmetic products	Category 3
Compost	Category 2 and 3
Production of biogas	Category 2 and 3
Production of thermal and electrical energy	Category 1, 2 and 3
Production of biofuel	Category 1, 2 and 3

[a] The current European Union document on the utilisation of animal by-products should be consulted for guidelines on handling and processing of these by-products.

One of the most common methods of converting solid wastes to value added products prior to these regulations is via the rendering process. This process uses heat treatment such as temperature of about 133 °C, a pressure of 3 bars and cooking time of about 20 min to separate the fat and the proteinaceous portion of animal wastes (Salminen and Rintala, 2002). The fat can then be used as raw material for producing cooking oil, soap, detergents and cosmetics while the protein residues are dried and grounded into feed meal such as meat and bone meal (MBM), feather meal and meat meal for livestock (Shareefdeen et al., 2005). However, since the outbreak of Bovine Spongiform Encephalopathy (BSE) the use of animal by-products for livestock feeding has come under strict regulation such that, only the low risk materials (category 3) are permitted even in pet foods and as organic fertilizers (Cascarosa et al., 2012). The feeding of ruminant animals with meals from animal by-products has been banned in the EU and in some other countries outside the EU. In addition, this ban was a welcome development for environmentalists who were concern about the environmental impacts of the odorous volatiles such as hydrogen sulphide, ammonia, ketones and aldehydes released from these animal wastes prior and during the rendering process (Shareefdeen et al., 2005; Gwyther et al., 2011).

Apart from rendering, farmers have long used animal wastes and carcasses for improving soil fertility. But improved knowledge in agriculture and animal husbandry has revealed the demerits of direct application of animal wastes to farmland. These demerits include the proliferation in the soil and transmission of pathogenic microorganisms to animals that graze on the land in addition to contamination of water bodies via leaching and emission of greenhouse gases in some cases. Hence, animal wastes are usually passed through the process of composting before application as organic fertilizers. Composting is an aerobic digestion process which converts organic waste materials (category 3 and excluding mortalities) into a soil like stable form which can be mixed with soil or used directly as medium for plant growth (Barrena et al., 2009). It is essentially a decomposition process involving thermophilic and mesophillic microorganisms. The heat generated by the action of the thermophiles inactivates the pathogens thus making it safe for application to soil. Although, it is widely accepted that animal by-products are viable compost raw material, very few literature references are available regarding their use since most studies made use of animal manure instead (Barrena et al., 2009). However, with respect to the process, there are some concerns about recontamination by opportunistic and pathogenic organisms and also about ammonia emission. In addition, as noted by the work of Barrena et al. (2009) the need to maintain a temperature within the range of 60–70 °C throughout the reactor makes this process to be prone to complication such as moisture loss which is due to the high airflow necessary to maintain a uniform temperature throughout the reactor. Hence, the process needs close monitoring, control of the initial material and process parameters such as temperature, aeration, moisture and C/N ratio, in order to guarantee safety and good quality compost.

Furthermore, organic wastes rich in protein and fat can be used to generate biogas (methane) via anaerobic digestion, which can serve as an alternative to fossil fuel. Volatile fatty acids (VVFs) derived from the fermentation of polypeptides, amino acids and long chain fatty acids undergo a series of reaction involving acetogenic and methanogenic microorganisms to produce methane and carbon dioxide. Salminen and Rintala (2002) gave an excellent review on the process of anaerobic digestion with emphasis on poultry slaughterhouse wastes. Palatsi et al. (2011) on the other hand reports the limiting effect of lipid biodegradability on the process kinetic and the need for microbial enrichment for successful anaerobic treatment. More so, some authors have pointed out the difficulty of anaerobic digestion of slaughterhouse wastes. These

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