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Valorisation of food waste to produce new raw materials for animal feed

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ABSTRACT

This study assesses the suitability of vegetable waste produced by food industry for use as a raw material for animal feed. It includes safety and nutritional viability, technical feasibility and environmental evaluation. Vegetable by-products were found to be nutritionally and sanitarily appropriate for use in animal feed. The drying technologies tested for making vegetable waste suitable for use in the animal feed market were pulse combustion drying, oven and microwave. The different meal prototypes obtained were found to comply with all the requirements of the animal feed market. An action plan that takes into account all the stages of the valorisation process was subsequently defined in agreement with local stakeholders. This plan was validated in a pilot-scale demonstration trial. Finally, the technical feasibility was studied and environmental improvement was performed. This project was funded by the European LIFE+ program (LIFE09 ENV/ES/000473).

1. Introduction

The fact that the Earth's population has been growing continuously over the last few hundred years, and therefore that the demand for natural sources has also increased, means that such resources are becoming increasingly scarce. As such, it is necessary to optimise their use in order to make them more sustainable. Humanity also generates thousands of tons of organic waste every day, most of which ends up as landfill, therefore the use of this waste as a raw material for feed formulation is an interesting alternative that deserves greater attention. In addition to reducing the environmental effect associated with animal feed production, valorisation of vegetable by-products for feed formulation would also maximise resource efficiency and contribute to competitiveness of feed producers by making available a more sustainable raw material which reduces the dependence on current raw materials (Myer, Brendemuhl, & Johnson, 2007; Westendorf, 2000; Westendorf, Dong, & Schoknecht, 1998). However, the use of vegetable waste as animal feed has some drawbacks that can limit its feasibility. For example, its high water content, which often exceeds 80%, makes handling more difficult and can accelerate the growth of microbiological contamination (García, Esteban, Márquez, & Ramos, 2005), thus meaning that a drying process is required. In addition, the analytical composition of such waste can vary markedly throughout the year (Westendorf, 2000), thus meaning that animal feed manufacturers have to change their feed formulations periodically depending on the composition.

Some studies in this field have indicated the feasibility of using vegetable waste in animal feed. Thus, a study of the solid organic waste generated in Salamanca (García et al., 2005) analysed different organic wastes, such as meat, fish, fruit and vegetables, restaurant and household waste, to determinate the chemical composition, microbiological characteristics and dioxin, furan, PCB and sand mineral contents for every type of waste fraction. This study concluded that it was possible to use vegetable and fruit by-products in animal feed formulations.

A subsequent study along the same lines (Esteban, García, Ramos, & Márquez, 2007) analysed these by-products as an alternative to traditional raw materials for pig feed and the influence of subsequent treatment on their digestibility. This study showed that fruit/vegetable waste had a high water content of 88.12 ± 1.84% and should thus be subjected to a drying process. The nutritional composition on a dry matter basis showed 65% nitrogen free extract, 13% crude fibre, 12% crude protein, 8% ash and 2% ether extract. To sum up, this waste mainly comprised carbohydrates (about 65%), which are the most important source of energy in swine metabolism, but had a high fibre content that reduces both the digestibility and available energy in pig diets. Although a minimum level of fibre is necessary for the digestive tract, the typical value for pig diets is about 5%. Consequently, a diet based on vegetable waste can be used but the addition of other ingredients is required.

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Taking into account these previous experiences, this study assesses the feasibility of reusing a mixture of vegetable and fruit wastes as a new raw material for animal feed.

2. Materials and methods

2.1. Characterization of vegetable waste

This study initially focused on characterization of the vegetable by-products. To this end, a full inventory of all Basque food industries that generate vegetable waste was developed with the aim of determining the amounts generated and their geographical dispersion. All the vegetable waste produced was identified by consulting previous studies and different private and public databases. The total amount of the different by-products generated by each sector, and the geographic dispersion of their production, was also quantified by contacting the associations that represent each sector and by submitting a questionnaire to the main representative companies in the Basque Country.

Subsequently, all vegetable by-products identified were analysed to determine the feasibility of their inclusion in feed formulations. All study parameters were determined by identifying legal requirements, regulated by the Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed and its transposition into the legislation of the countries, and feed-market requirements that a raw material for animal feed must fulfil. Therefore, the undesirable substances studied were; nitrites, mycotoxins (aflatoxin B1, B2, G1 y G2, zearalenone, deoxynivalenol, ochratoxin A, fumonisin B1 and B2, T-2 toxin, HT-2 toxin and patuline), pesticides (aldrin, chlordane, DDT, endosulfan, endrin, HCH, hexachlorocyclohexane, heptachlor and hexachlorobenzene), heavy metals (lead, cadmium, arsenic and mercury), microbiological analyses (salmonella, listeria, Escherichia coli, Staphylococcus aureus, Clostridium perfringens, sulfite-reducing clostridia, aerobic mesophiles, enterobacteriaceae, total coliforms), molds-yeast and dioxins levels. Undesirable substances and their maximum legal limits were studied together with the ELIKA Foundation, a Basque technological for food and feed safety. Moreover, some nutritional parameters were also studied: water content, ash content, protein levels, fibre content, starch level, fat level, sugars level, caffeine and pH. The nutritional results were studied together with EPEA Association (Feed Manufacturers Association of the Basque Country), which represents 11 feed manufactures located in the Basque Country. Once all parameters were defined, the sampling plan was divided into three different periods throughout the year (spring, summer/autumn and winter), to study how the composition of these by-products varies with season and two of the most representative companies in each sector were identified as sampling points. Moreover, in order to ensure the representativeness of the samples, and therefore allow a comparison of the different samples, a sampling protocol was defined to ensure that all samples were taken in the same conditions. Thus, two samples of 1 kg were taken from each sampling point and the A samples were sent to analyse immediately to avoid degradation, without any further treatment other than grinding and homogenisation, and the B samples were frozen just in case the analysis had to be repeated. The sampling and analysis methods were carried out taking into account the Commission Regulation (EC) No 152/2009 of 27 January 2009 laying down the methods of sampling and analysis for the official control of feed.

2.2. Definition of the drying process

A drying process was defined with the aim of making the mixture of vegetable waste more stable over time. The drying process minimizes the water activity, and therefore contributes to the microbiological stability, by reducing the water content to less than 12% (Fig. 1, Eskin & Robinson, 2000). In addition, it should ensure that the nutritional composition does not undergo important changes and that no additional undesirable substances are generated.

The different drying technologies to be tested were selected by consulting previous studies and the literature in order to identify the most efficient technologies previously used to dry vegetable products: Microwave (Motevali, Minaei, & Khoshtagaza, 2010; Sharma & Prasad, 2005; Zhang, Tang, Mujumdarc, & Wang, 2006), Pulse Combustion Drying (PCD) (Zbicinski, 2002; Zbicinski, Smucerowicz, Strumillo, & Crowe, 2000), Static and Rotary Oven (McMinn & Magee, 1999; Motevali et al., 2010; Pinacho, García-Encina, Sancho, Ramos, & Márquez, 2005; Vega-Gálvez et al., 2009) and others (Besombes, Berka-Zougali, & Allaf, 2010; Lewicki, 2006; Maache-Rezzoug et al., 2008).

Once the analytical feasibility was assessed, different types of vegetable waste were taken following the sampling protocol. They were immediately mixed in a proportional way by assessing the availability and seasonality of each kind of vegetable waste throughout the year in order to ensure homogeneity in terms of meal composition. The mixture obtained was crushed and homogenised to ensure the feasibility of the drying process.

Subsequently, and in order to develop a safe and efficient drying process, initial trials were carried out with the aim of defining all parameters and conditions of the drying process: temperature, time, power consumption, etc. Once these parameters and conditions were identified, exhaustive drying trials were carried out for each technology to optimise the final drying process and to obtain different vegetable flour prototypes. Finally, the feasibility of each drying technology was assessed by analysing all the prototypes obtained in order to determine whether they fulfilled all legal and market requirements previously identified for use as a raw material for animal feed.

2.3. Definition of the action plan

The action plan for a sustainable, efficient and innovative recovery of vegetable wastes for animal feed describes in detail all the stages that are necessary for the feasible recovery of the mixture of vegetable by-products as a raw material for animal feed. It must guarantee the safety of the animal feed and compliance with the

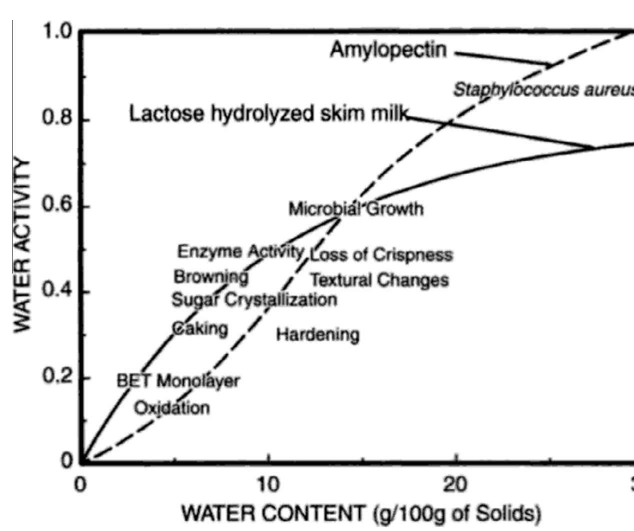

Fig. 1. Critical water activity and water content ranges for various changes and microbial growth occurring in food materials (Eskin et al., 2000).