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Changes in nutrient content of sweet pepper waste after colonisation by dairy *Penicillium**

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Abstract - Sweet pepper waste was examined before and after colonisation with *Penicillium roqueforti* Pr1. Fungal growth increased crude protein content from 22.3 to 35.2 (% dry matter), gross energy from 4763 to 4899 (Kcal kg^{-1} DM), neutral detergent fiber content from 22.3 to 48.4 (% dry matter), and acid detergent fiber content from 17.5 to 38.6 (% dry matter). On the contrary, fungal growth decreased usable organic matter from 66.0 to 40.2 (% dry matter) and non-nitrogen usable organic matter from 35.7 to 5.0 (% dry matter).

Key words: sweet pepper waste, *Penicillium roqueforti*, solid-state fermentation, animal feed.

INTRODUCTION

Sweet pepper waste is an industrial by-product frequently used as feedstuff for animals. Microbial growth could improve its digestibility and nutritional value. Solid-state fermentation of citrus pulps with dairy *Penicillium* notably increases crude protein content, gross energy, and structural carbohydrates (Scerra *et al.*, 1999a; 1999b).

This research aims to improve the nutritional value of sweet pepper waste by solid-state fermentation with dairy moulds for application in animal feed.

MATERIALS AND METHODS

Screening. Seven strains of *Penicillium camemberti* (Pc) and four strains of *Penicillium roqueforti* (Pr) isolated from commercial cheeses were employed. Sweet pepper waste, from GIAT of Mongrassano Scalo (CS), Italy, was cut into 5 cm

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FIG. 1 – The experimental tunnel used for fungal colonisation of sweet pepper waste.

pieces, divided into 100 g portions and pasteurised at 100 °C for 20 min. A 5 ml fungal spores suspension (10^6 spores/ml) of each strain was inoculated into the pasteurised waste and incubated at 25 °C for 10 d. Rate and uniformity of growth were evaluated by visual examination; in addition, pH, dry matter and crude protein were determined before and after colonisation.

Scale-up. The best strain was inoculated into 100 g of pasteurised waste and incubated at 25 °C. After 7 d this was added to 1 kg of pasteurised waste. After 7 d this was added to 10 kg of pasteurised waste. After a further 7 d the resulting preculture was inoculated into 100 kg of unpasteurised waste. Solid-state fermentation was carried out for 10 d at room temperature in an experimental semicylindrical tunnel, 200 cm long and 80 cm wide, made of black plastic film, supported on three hoops 50 cm high. Two frontal openings facilitated air circulation (Fig. 1). Before and after fungal colonisation, pH, dry matter, ash, organic matter, ether extract, crude protein, gross energy, neutral detergent fiber, acid detergent fiber, hemicellulose, cellulose, and lignin were determined in duplicate according to Martillotti *et al.* (1987). By subtracting the neutral detergent fiber from the organic matter, the usable organic matter was calculated. By subtracting the crude protein from the usable organic matter, the non-nitrogen usable organic matter was calculated.

RESULTS AND DISCUSSION

Screening

After 10 d, only strains Pc7, Pr1, and Pr4 completely covered the surface of the waste. The pH, initially 5.0, after fungal growth varied from 4.4 (strain Pc8) to 6.0 (strain Pc4). The dry matter (DM), initially 8.0%, decreased, ranging from 6.3 (strain Pc1) to 7.8% (strain Pc2). The crude protein content, initially 22.3% DM, increased, ranging from 22.9 (strain Pc4) to 32.3% DM (strain Pr1). Pr1 was chosen as the best strain.

Scale-up

Table 1 reports the changes produced by the growth of strain Pr1 on 100 kg of unpasteurised waste. The pH increased by about one unit; this could be useful in animal feed. The dry matter increased by 13.8%, presumably due to evaporation. Ash and organic matter were substantially unchanged. The non-nitrogen usable

organic matter decreased by 86.1% and the usable organic matter decreased by 39.1%, due to microbial utilisation. The ether extract decreased by 23%, due to the lipolytic activity of the mould. The crude protein content increased by 58%, due to the fungal proteins; in addition, the essential amino acids might also be improved by microbial growth (Mathot *et al.*, 1992). Gross energy increased, probably as a result of the consumption of usable carbohydrates (4.21 cal g^{-1}) and the synthesis of microbial proteins (5 cal g^{-1}). The percentages of neutral detergent fiber, acid detergent fiber, hemicellulose, and cellulose doubled, and that of lignin tripled. These increases are partly due to the decrease of other dry matter components (e.g. usable organic matter) and because these structural carbohydrates (e.g. hemicellulose) are the main constituents of the fungal cell wall (Chavez *et al.*, 1988). In addition, the higher lignin value could also be due to the formation of Maillard's products, by reaction between lignin and proteins.

TABLE 1 – pH and chemical composition of sweet pepper waste before and after colonisation by *P. roqueforti* Pr1

Parameter*	Waste before colonisation	Waste after colonisation
pH	5.0 ± 0.1	5.9 ± 0.1
DM (%)	8.0 ± 0.09	9.1 ± 0.05
A (% DM)	11.7 ± 0.1	11.4 ± 0.1
OM (% DM)	88.3 ± 0.07	88.6 ± 0.08
UOM (% DM)	66.0 ± 0.08	40.2 ± 0.09
NNUOM (% DM)	35.7 ± 0.1	5.0 ± 0.07
EE (% DM)	6.4 ± 0.01	4.9 ± 0.02
CP (% DM)	22.3 ± 0.03	35.2 ± 0.01
GE (Kcal kg^{-1} DM)	4763 ± 0.5	4899 ± 0.5
NDF (% DM)	22.3 ± 0.08	48.4 ± 0.08
ADF (% DM)	17.5 ± 0.08	38.6 ± 0.08
HC (% DM)	4.8 ± 0.1	9.7 ± 0.1
Ce (% DM)	12.2 ± 0.1	23.3 ± 0.07
L (% DM)	5.2 ± 0.07	15.4 ± 0.09

* DM (dry matter), A (ash), OM (organic matter), UOM (usable organic matter), NNUOM (non-nitrogen usable organic matter), EE (ether extract), CP (crude protein), GE (gross energy), NDF (neutral detergent fiber), ADF (acid detergent fiber), HC (hemicellulose), Ce (cellulose), L (lignin).

Solid-state fermentation with *Penicillium roqueforti* Pr1 appears an economical technique for enriching sweet pepper waste in the wet state with microbial proteins. Colonisation with dairy *Penicillium* produces a number of changes: thus, it is important, for the evaluation of its use for animal feed, to assess the digestibility *in vitro* and *in vivo* after fungal colonisation.

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