Production of orange peel-based ingredients for dairy sheep feed in pilot scale

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Introduction

The aim of this study was the valorisation of orange peels towards the production of orange peel-based ingredients for dairy sheep feed. Within this valorisation strategy, the enzymatic hydrolysis of orange peels is the first process unit, from which a liquid fraction rich in sugars and a hydrolysed solid residue are obtained. The liquid fraction is used for yeast cultivation with the ultimate goal of producing single cell protein. The latter is mixed with the hydrolysed solid residue to produce advanced animal feed. The final feedstuff is dried in order to stabilise the product in terms of shelf life and feed safety. The whole valorization process is illustrated in Figure 1.

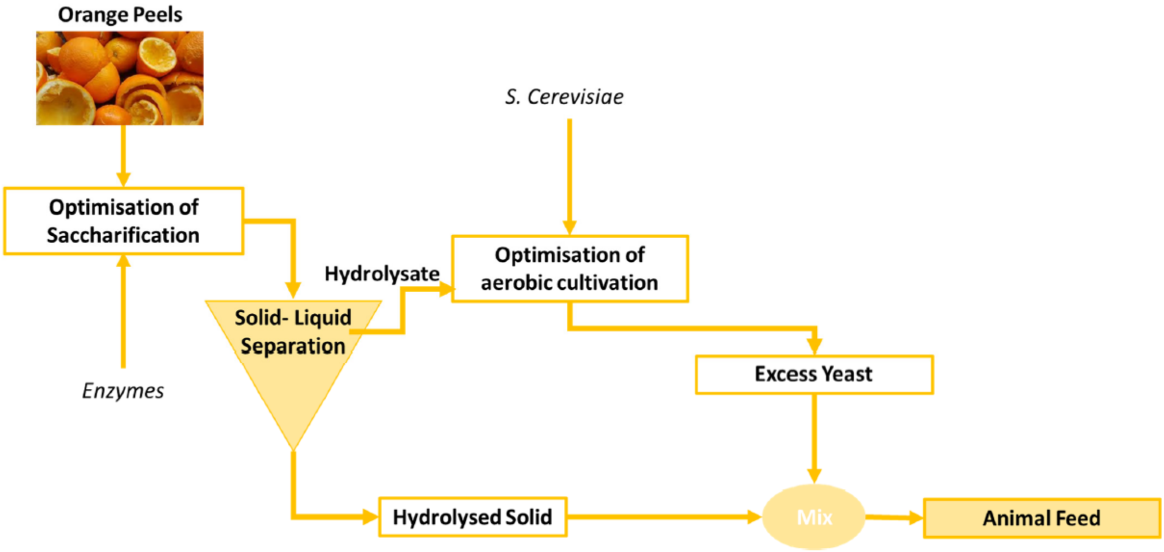

Figure 1. Flow diagram of valorisation strategy of orange peels

Materials and Methods

Raw material**:** Hellenic Fruit Juices provided the feedstock to NTUA and its composition is presented in Table 1.

Table 1. Composition of unprocessed and processed orange peel-based ingredient prepared in pilot trials

Parameter	Unprocessed orange peels	Processed orange peels
Total Solids	91.85±1.65	93.34±1.92
Moisture	8.15±1.65	6.66±1.92
Volatile Solids (% d.b.)	91.35±1.78	92.83±2.01
Ash (% d.b.)	8.65±1.78	7.17±2.01
Oils (% d.b.)	0.25±0.01	0.32±0.03
Water Soluble Solids (% d.b.)	35.99±1.98	36.85±2.21
Cellulose (% d.b.)	17.47±2.12	15.51±1.78
Hemicellulose (% d.b.)	30.70±4.46	23.34±3.41
Acid Soluble Lignin (% d.b.)	1.06±0.08	0.81±0.03
Acid Insoluble Lignin (% d.b.)	10.70±1.11	12.36±0.98
TN (% d.b.)	1.38±0.04	3.66±0.07
Crude protein (%d.b..)	8.63±2.39	22.88±2.43
NDF (% d.b.)	34.10±3.21	26.74±3.42
ADF (% d.b.)	24.80±3.43	23.81±3.87
ADL (% d.b.)	6.20±2.16	8.30±2.01

Saccharification: According to lab scale optimization study (Andrianou *et al*., 2023), the optimum conditions for the saccharification process were defined to be 50ºC, 7.5% solids loading, Pectinex 25μL/g TS, CellicCTec3 25 μL/g TS for 24h. More specifically, the enzymatic saccharification of orange peels was conducted in the 200L bioreactors of the pilot plant. By the end of the saccharification process, the hydrolysate was sieved and the solid fraction was removed from the liquid. The remain liquid was used as substrate for the subsequent aerobic fermentation step.

***Aerobic Fermentation*:** After the enzymatic saccharification in the bioreactors, the hydrolysate of the saccharification process, free of suspended solids was loaded to the bioreactor. Upon measurement of the glucose concentration, nutrients and yeast were added. The mixing was vigorous and an aerated recirculation tank was used in order to provide adequate aeration. The aerobic fermentation was conducted at 30°C for 72h. By the end of these trials, the produced biomass was sieved and collected. The concentration of ethanol, glucose, TRS, TOC, TN was monitored during the experimental trials.

Drying process: The processed orange peels produced from the pilot plant were dehydrated and simultaneously milled by a food waste dryer (GAIA GC-100). The dehydration was performed at 50 °C for almost 20 h/cycle aiming to avoid all possible microbial development but also to avoid alterations in the feedstock composition. The simultaneous milling resulted in a homogeneous coarse powder feedstock.

Results and Discussion

A continuous operation of the plant took place including pilot trials. The performance of the saccharification process was very reproducible and the final glucose concentration was 12.82±4.70 g/L. The solids hydrolysis/degradation was high; over 80% in all cases. Table 2 presents the mean values of the liquid phase characteristics at the beginning and at the end of the saccharification process.

Table 2. Characteristics of the liquid phase at the begining and at the end of the saccharification process

Parameter	Start (t=0h)	End (t=24h)
Glucose (g/L)	4.73±0.12	12.82±4.70
TRS (g/L)	4.62±0.09	35.60±2.32
TN (mg/L)	220.85±9.81	366.18±11.21
TOC (g/L)	14.25±2.34	29.11±6.45
TSS (%)	7.50±1.01	1.28±0.08

It is evident that the enzymatic hydrolysis of pectin and cellulose was successful and the release of sugars in the form of glucose and TRS was also high, reaching 0.108 g glucose per g of orange peels (d.b.) and 0.413 g TRS per g of orange peels (d.b.). Apart from the sugars release, the hydrolysis process resulted in the release of nitrogenous and other organic compounds as indicated by the concentrations of TN and TOC respectively. The energy consumption was monitored, and the average consumption of each bioreactor (200L) was estimated 36kWh per cycle. The pre-heating of the bioreactor at 50ºC contributed 35% to the total energy consumption, while the rest energy was consumed for the heating and mixing purposes during the 24-hour saccharification process.

In the next step, the aerobic fermentation of the released sugars took place, and the final ingredient was collected after filtration. In all cases, glucose was totally consumed, while TRS concentration was reduced over 85%. The TSS concentration was increased from 1.28±0.08% to 3.3±0.1%, indicating a satisfactory biomass yield. In view of minimization of use of fresh water, enzymes and chemical additives, the effluent from one cycle was used in the next one. Up to 3 times recirculation did not affect the performance of the process.

The composition of the prepared orange peel-based ingredient is presented in the Table 1. The processed orange peels presented elevated protein content, meeting the objectives of the applied strategy. It is worth noticing that the feedstuff prepared presented elevated protein content and lower NDF, implying its superiority as animal feed.

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References

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