Alternative valorisation pathways for orange peel waste

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Introduction

Orange juice industries produce orange juice as well as orange peels as their main solid waste. From an industrial point of view, an orange can be considered as a composite of 43% juice and 57% peel and pulp. Thus, for single-strength juice 1,33 kg peels are produced per litre of juice, while the respective value for concentrated juice is over 2,85 kg/L. According to latest FAO statistical data (2019), the geographical distribution of juice production and the respective peels production are presented in Figure 1. Therefore, the potential of peels production is over 8 million tons globally and nearly 600000 tons in Europe. In the context of circular economy, the valorisation of orange peels is of high priority given their high availability and composition. Within this work, alternative valorisation pathways such as animal feedstuff, ethanol and/or biogas production are studied.

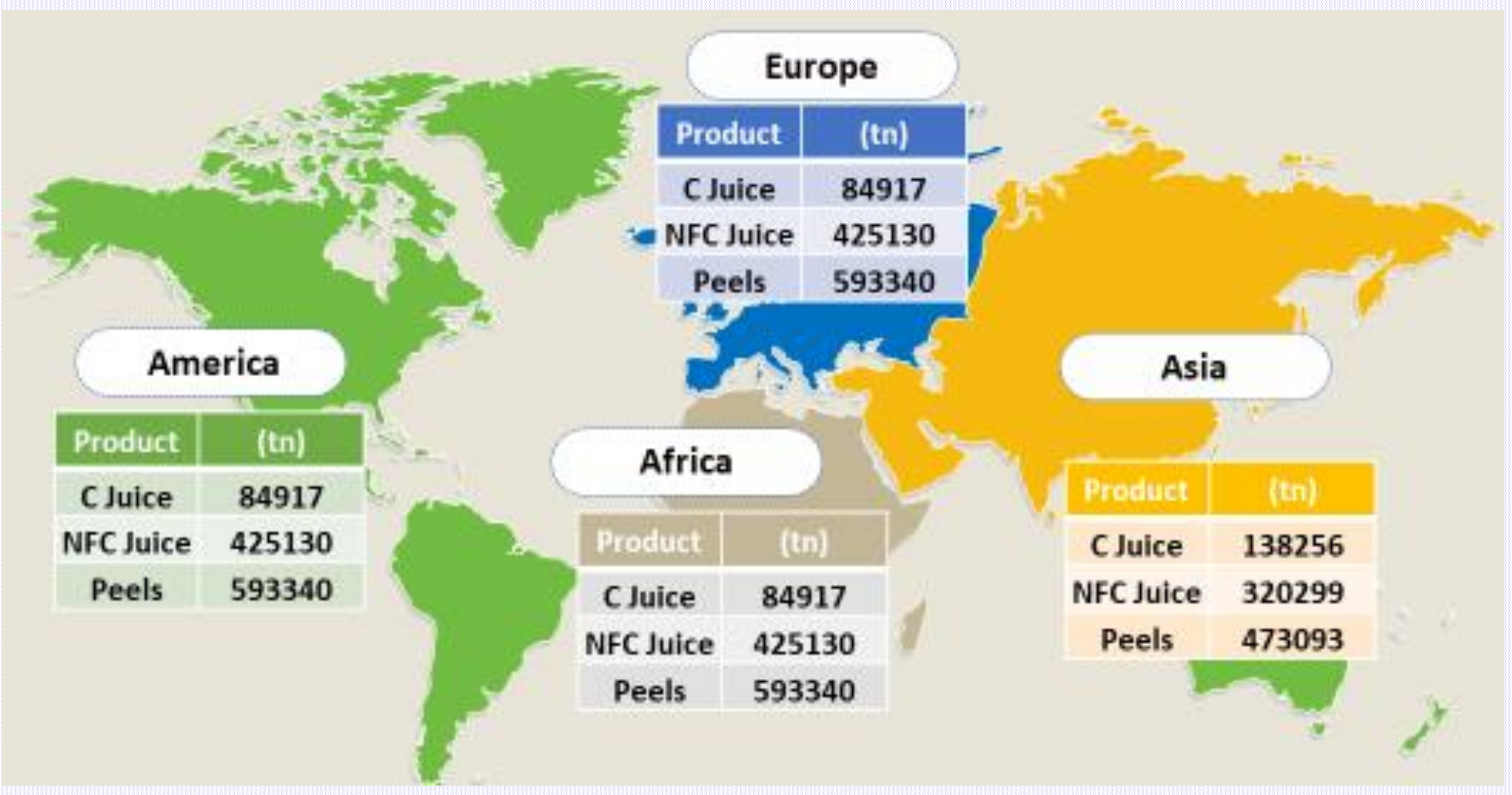

Figure 1. Geographical distribution of annual production of orange juice production and resulting orange peels (2019)

Results & Discussion

The physicochemical characteristics and nutritional value of the dried unprocessed orange peels on dry basis (%w/w) are presented in Table 1. For a balanced ruminants' diet, Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) should be over 28% and 19% respectively, while Non-fibrous Carbohydrate (NFC) should be below 38%. Thus, from the nutritional analysis, it can be concluded that the feedstock could stand as a secondary component for a balanced ruminants' diet.

Table 1. Physicochemical and Nutritional characteristics of orange peels

Parameter	Value
TS (%)	91,27
Moisture (%)	8,73
ASH (%)	4,81
VS (%)	95,19
Oil (%)	2,71
TN(%)	1,15
Crude Protein (%)	7,18
Cellulose (%)	20,58
Hemicellulose (%)	24,62
Acid Insoluble Lignin (%)	12,98
Ether extract (%)	3,57
Neutral detergent fibre (NDF), (%)	72,0
Acid detergent fibre (ADF) (%)	40,4
Lignin Acid Detergent (ADL) (%)	26,6

Enzymatic saccharification of cellulose was performed at 50ºC by the addition of a cellulolytic formulation; CellicCTec2 (Novozymes, Denmark) for 24h. Dosages of 0, 50, 150, 300 and 450 μL enzyme/g cellulose were adopted. Bioconversion of the glucose produced to bioethanol via ethanolic fermentation was achieved by the addition of Saccharomyces cerevisiae (2% w/w) in the same autoclavable bottles, at 30°C for 24h. The biogas potential of the stillage was also examined.

Table 2. Saccharification and ethanol yields of enzymatic hydrolysis and ethanolic fermentation performed with CellicCTec2, along with biogas potential (BP) of stillages

A/A	Cellic CTec2 (μL enzyme/g cellulose)	Saccharification Yield (%)	Ethanol Yield (%)	Ethanol Yield (mg ethanol/g wet feedstock)	BP (mL/g VS)
1	0	37,1	66,9	9,62	443
2	50	52,7	89,7	12,33	243
3	150	78,6	58,4	8,03	507
4	300	83,6	55,0	7,56	530
5	450	52,7	27,3	3,75	159

The biogas potential of the unprocessed orange peels was equal to 655.37 mL/g VS. Figure 2 summarizes the alternative valorisation routes of 1000kg orange peels waste feedstock. Apart from the products on mass basis, their energy content is also presented. Additionally, the products index (PI) is calculated as the input to products efficiency in terms of mass.

CellicTec2 (μL enzyme/g cellulose)	Biogas (L)	Ethanol (L)	Energy Content (MJ)	PI (%)
0	40525	12	1393	5,88
50	26312	16	1067	4,43
150	**51869**	**10**	**1668**	**7,10**
300	50014	10	1603	6,83
450	18776	5	626	2,65

Figure 2: Alternative valorisation routes of orange peels.

Conclusions

Conclusively, the production of animal feedstuff is the valorisation route with the highest product index (10,29%). From an energy viewpoint, 1632 MJ energy (biogas) are obtained from the anaerobic bioconversion of one ton of orange peels to biogas. Nearly the same energy content is achieved in the optimum scenario of bioethanol production followed by the production of biogas. At this point, it should also be noted that bioethanol as liquid biofuel is preferable to biogas for numerous reasons (storage, transportation, existing network etc.). Thus, it was made evident that orange peels can stand as a suitable feedstock for high quality biobased products, which could contribute substantially to bioeconomy.

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