



Deconstruction of banana peel for carbohydrate fractionation

Maria Angélica F. Pereira¹ · Carla Roana M. Monteiro¹ · Gabriela N. Pereira¹ · Sidnei E. Bordignon Júnior¹ · Eduardo Zanella² · Patrícia F. Ávila³ · Boris U. Stambuk² · Rosana Goldbeck³ · Débora de Oliveira¹ · Patrícia Poletto¹

Received: 8 July 2020 / Accepted: 6 September 2020 / Published online: 18 September 2020
© Springer-Verlag GmbH Germany, part of Springer Nature 2020

Abstract

The deconstruction of banana peel for carbohydrate recovery was performed by sequential treatment (acid, alkaline, and enzymatic). The pretreatment with citric acid promoted the extraction of pectin, resulting in a yield of 8%. In addition, xylose and XOS, 348.5 and 17.3 mg/g xylan, respectively, were also quantified in acidic liquor as a result of partial depolymerization of hemicellulose. The spent solid was pretreated with alkaline solution (NaOH or KOH) for delignification and release of residual carbohydrates from the hemicellulose. The yields of xylose and arabinose (225.2 and 174.0 mg/g hemicellulose) were approximately 40% higher in the pretreatment with KOH, while pretreatment with NaOH promoted higher delignification (67%), XOS yield (32.6 mg/g xylan), and preservation of cellulosic fraction. Finally, the spent alkaline solid, rich in cellulose (76%), was treated enzymatically to release glucose, reaching the final concentration of 28.2 g/L. The mass balance showed that through sequential treatment, 9.9 g of xylose, 0.5 g of XOS, and 8.2 g of glucose were obtained from 100 g of raw banana peels, representing 65.8% and 46.5% conversion of hemicellulose and cellulose, respectively. The study of the fractionation of carbohydrates in banana peel proved to be a useful tool for valorization, mainly of the hemicellulose fraction for the production of XOS and xylose with high value applications in the food industry.

Keywords Banana peel · Hemicellulose · Xylooligosaccharides · Cellulose · Chemical pretreatment · Enzymatic hydrolysis

Introduction

The banana (*Musa acuminata*) is an edible fruit with excellent acceptability, easy access, low cost, and available in large quantities, especially in tropical countries, where it is a common agricultural crop [1]. The amount of waste generated in banana processing is significant; in fact, the peel corresponds to 35–40% of the weight of the fresh fruit [2, 3]. In 2018, Brazil produced 6.7 million tons of bananas, which is equivalent to 2.7 million tons of peel generated [4]. This

type of agricultural waste is usually disposed in landfills and/or used for agricultural fertilization. Although high-value co-products can be generated from banana cultivation, only a small part of the total volume of banana peels has been explored, mainly as an ingredient rich in dietary fiber [5].

Banana peels are made up of insoluble dietary fiber represented by cellulose (18.7%), hemicellulose (20.3%) and lignin (16.8%) [6], and soluble dietary fiber represented by pectin (15.9%) [7]. Cellulose is an unbranched, rigid, and highly crystalline polymer, formed by glucose units with β -1,4 type bonds [8], while hemicellulose is a heteropolysaccharide composed of different proportions of sugars, such as xylose, arabinose, galactose, and mannose. Xylan, the major hemicellulose of most plants, is formed by β -1,4-xylose units in the main linear chain, but it also has a branched structure decorated with substituent groups, such as arabinose, galactose, glucose, acetic acid, and uronic acid units [9]. The main xylan chain has the potential to produce several biomolecules of added value, including xylitol and prebiotic xylo-oligosaccharides [10]. Arabinose is the second most abundant sugar attached to the linear xylan backbone, playing an important structural role in binding to cellulose

✉ Patrícia Poletto
patricia.poletto@ufsc.br

¹ Laboratory of Biological Engineering, Department of Chemical and Food Engineering, UFSC – Federal University of Santa Catarina, Florianópolis, SC 88040-970, Brazil

² Yeast Molecular Biology and Biotechnology Laboratory, Department of Biochemistry, Federal University of Santa Catarina, Florianópolis, SC, Brazil

³ Laboratory of Bioprocess and Metabolic Engineering, Department of Faculty of Food Engineering, UNICAMP - University of Campinas, Campinas, SP 13083-862, Brazil



Hydrothermal treatment on depolymerization of hemicellulose of mango seed shell for the production of xylooligosaccharides

Carla R.M. Monteiro^a, Patrícia F. Ávila^b, Maria Angélica F. Pereira^a, Gabriela N. Pereira^a,
Sidnei E. Bordignon^a, Eduardo Zanella^c, Boris U. Stambuk^c, Débora de Oliveira^a,
Rosana Goldbeck^b, Patrícia Poletto^{a,*}

^a Laboratory of Biological Engineering, Department of Chemical and Food Engineering, Federal University of Santa Catarina, Florianópolis, SC, Brazil

^b Bioprocess and Metabolic Engineering Laboratory, School of Food Engineering, Department of Food Engineering, University of Campinas, Campinas, SP, Brazil

^c Yeast Molecular Biology and Biotechnology Laboratory, Department of Biochemistry, Federal University of Santa Catarina, Florianópolis, SC, Brazil

ARTICLE INFO

Keywords:

Mango waste
Xylooligosaccharides
Xylan
Waste valorization
Lignocellulosic biomass

ABSTRACT

Hydrothermal processing is an interesting biorefinery technology for converting lignocellulosic biomass into biofuels and biocompounds. This process is based on the selective solubilization and depolymerization of hemicellulose fraction (xylan) and may be considered beneficial, due to the possibility of obtaining xylooligosaccharides (XOS) with a degree of polymerization (DP) suitable for prebiotic applications. This study evaluated the effect of pressure (2.5 and 10 MPa) in a kinetic study (30 min) of hydrothermal treatment (180 °C) to optimize the extraction of XOS from mango seed shell. Total reducing sugars (TRS) values were close to the maximum in 15 min showing a slower rate for both pressures after this time, but at 10 MPa the value was 20 % lower than at 2.5 MPa. Based on these results, a new extraction was performed at 2.5 MPa and 15 min, and the extracted XOS were quantified, yielding 393.44 mg XOS/g xylan. XOS with a degree of polymerization between X2-X6 corresponded to 82.24 mg/g and XOS with X > 6 (or soluble xylan) corresponded to 311.20 mg/g. A low amount of xylose (8.81 mg/g xylan) was released, resulting in a hemicellulose conversion of 40.2 %. In general, approximately 8.1 kg of total XOS was produced from 100 kg of dried mango seed shell (X2-X6–1.7 kg and X > 6–6.4 kg).

1. Introduction

The food industry produces a significant amount of lignocellulosic biomass made up of cellulose, lignin and hemicellulose. These fractions can produce a number of products with high added value such as xylooligosaccharides (XOS) derived from hemicellulose. While residues are extensively studied, they are still underutilized to obtain XOS. As a result, the exploitation of waste by industries for the production of XOS may be of interest from an economic and environmental point of view, as it is an abundant and renewable resource (Liguori & Faraco, 2016; Otieno & Ahiring, 2012).

XOS are non-digestible saccharides with prebiotic action (Otieno & Ahiring, 2012). Currently, corncob and sugarcane bagasse are currently used industrially for the production of XOS (Amorim, Silvério, Prather, & Rodrigues, 2019; Poletto et al., 2020). However, new studies are

underway to obtain XOS from other biomasses such as pineapple peel, brewery residues, chestnut shell, peanut shell, among others (Arumugam, Biely, Puchart, Singh, & Pillai, 2018; Banerjee, Patti, Ranganathan, & Arora, 2019; González-García, Morales, & Gullón, 2018; Gullón, Eibes, Dávila, Moreira, et al., 2018). Residues from mango processing are part of the volume of lignocellulosic residues available. According to FAO (2019), approximately 100 million tons of mango were produced worldwide in 2018. The main by-products generated are the peel and the stone, which constitute between 35 and 60 % of the fruit (Dorta, Lobo, & González, 2012). The stone, consisting of shell and kernel, has already been used in the production of animal feed (Henrique, Silvério, Flauzino Neto, & Pasquini, 2013), glucose, activated carbon (Elizalde-González & Hernández-Montoya, 2007), and vegetable butter due to its fat content (about 15 %) (Jahurul et al., 2015). Mango seed shell (MSS) consists of 16 % hemicellulose (Elizalde-González & Hernández-Montoya, 2007);

* Corresponding author at: Federal University of Santa Catarina (UFSC), Department of Chemical and Food Engineering (EQA), Campus Trindade, PO box 476, 88010-970 Florianópolis, SC, Brazil.

E-mail address: patricia.poletto@ufsc.br (P. Poletto).

<https://doi.org/10.1016/j.carbpol.2020.117274>

Received 15 April 2020; Received in revised form 14 October 2020; Accepted 16 October 2020

Available online 21 October 2020

0144-8617/© 2020 Elsevier Ltd. This article is made available under the Elsevier license (<http://www.elsevier.com/open-access/userlicense/1.0/>).



From Biorefinery to Food Product Design: Peach (*Prunus persica*) By-Products Deserve Attention

Carla Roana Monteiro Rudke¹ · Acácio Antônio Ferreira Zielinski¹ · Sandra Regina Salvador Ferreira¹

Received: 23 August 2022 / Accepted: 14 November 2022 / Published online: 24 November 2022
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2022

Abstract

There is an increasing demand for functional foods to attend the consumers preference for products with health benefits. Peach (*Prunus persica*), from Rosaceae family, is a worldwide well-known fruit, and its processing generates large amounts of by-products, consisting of peel, stone (seed shell + seed), and pomace, which represent about 10% of the annual global production, an equivalent of 2.4 million tons. Some studies have already evaluated the bioactive compounds from peach by-products, although, the few available reviews do not consider peach by-products as valuable materials for product design methodology. Thereby, a novelty of this review is related to the use of these mostly unexplored by-products as alternative sources of valuable components, encouraging the circular bioeconomy approach by designing new food products. Besides, this review presents recent peach production data, compiles briefly the extraction methods for the recovery of lipids, proteins, phenolics, and fiber from peach by-products, and also shows in vivo study reports on anti-inflammatory, anti-obesity, and anti-cerebral ischemia activities associated with peach components and by-product. Therefore, different proposals to recover bioactive fractions from peach by-products are provided, for further studies on food-product design.

Keywords Design thinking · Circular economy · Bioactive ingredients · Sustainable processes

Introduction

The search for sustainable industrial processes has guided the production of chemicals and fuels from biomass-based economy (Arora et al., 2018). However, millions of ton of by-products from food processing industry are currently generated worldwide, being disposed of in landfills, used in composting or for animal feed (Rico et al., 2020). The industry is dealing with the increasing interest in naturalness as current and future trends in global trades. The companies, aware of the consumers demands, are continuously looking for process innovations to maintain the natural characteristics of the products. Therefore, understanding the concept of

product design is highly relevant for the development of food products, warranting naturalness attributes. Firstly, the highest challenge for companies is understanding the customer's necessities and capture their attention, transforming the consumer's ideas into chemical and physical parameters of the final product, improving its appeal (Taifouris et al., 2020). Therefore, in order to attend these demands, the companies must follow modern and innovative technologies to provide competitive and sustainable products, resulting in optimized food production with less water and energy consume, and also better use of edible and non-edible parts of food raw materials and supplies. Consequently, the companies need to improve the design, optimization, and development of different formulations and techniques, before introducing new food products to the market (Granato et al., 2020).

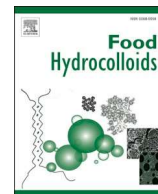
Besides, it is essential to change the form of production, converting the linear economy into a sustainable circular bioeconomy. The philosophy of the dominant economic model of “take, make and dispose” must be urgently transformed into a sustainable model (Maina et al., 2017). For that, the concept of upcycled foods, which is the use of food ingredients or processed food materials, that would, otherwise, be discarded, must be properly understood (Goodman-Smith

✉ Sandra Regina Salvador Ferreira
s.ferreira@ufsc.br

Carla Roana Monteiro Rudke
carla.roana@posgrad.ufsc.br

Acácio Antônio Ferreira Zielinski
acacio.zielinski@ufsc.br

¹ Chemical and Food Engineering Department,
Federal University of Santa Catarina, PO Box 476,
88040-970 Florianópolis, SC, Brazil



Comparing green extraction methods for the recovery of protein-rich fraction from peach seeds (*Prunus persica*)

Carla Roana Monteiro Rudke, Talyta Mayara Silva Torres, Acácio Antônio Ferreira Zielinski, Sandra Regina Salvador Ferreira*

Chemical and Food Engineering Department, Federal University of Santa Catarina, PO Box 476, 88040-970, Florianópolis, SC, Brazil

ARTICLE INFO

Keywords:

Functional properties
Coproducts
Oily fraction
Non-animal protein
Emergent techniques

ABSTRACT

Peach processing generates significant volume of coproducts, such as the underutilized peach seeds, which are rich in fatty acids and protein. The recovery of protein-rich fractions from peach seeds is highly relevant because of the increasing demand for alternative non-animal protein sources. This study aimed to investigate different extraction techniques for protein recovery from the underestimated peach seeds, and evaluate the functionalities of the protein fraction. The peach seeds were defatted using the supercritical fluid extraction (SFE-CO₂), with oily recovery up to 29.53% ± 0.45. Then, the protein fraction was recovered using the following methods: heat-stirred extraction (HSE) as a conventional method, and, as alternative procedures, microwave-assisted extraction (MAE), pressure liquid extraction (PLE), and ultrasound-assisted extraction (UAE) using NaOH solution as solvent. The PLE provided the highest protein content (95.10 % ± 0.98), followed by the HSE technique (55.09% ± 0.35). Furthermore, the PLE showed the best performance in techno-functional properties of the protein fraction: emulsion activity, foaming, turbidity, free sulfhydryl content, hydrophobicity, and color, compared to the classical HSE technique. Therefore, it is suggested that PLE (10 min) method recovered an isolated protein with better functional properties, providing promising result for protein purification. Therefore, PLE can be considered an alternative method to add value to underestimated peach seeds, conferring the upcycling concept.

1. Introduction

The food industry has increased its interest in alternative protein sources (Kahraman et al., 2022). According to Rivera Del Rio et al., 2022, the plant-based protein market could constitute up to 15% of the total protein market until 2035. Moreover, the consume of plant-based proteins from different sources is related to ethnic, cultural, and sustainable aspects (Rivera Del Rio et al., 2022). The growth of this market also contributes to increase the search for alternative protein sources. Besides, more efficient protein production has been focused on plant coproducts as interesting and low-cost sources of protein (Alvar ez-Ossorio et al., 2022a). As to indicate the seeds as an alternative processing material, it is important to observe the world production of peaches and nectarines in 2020, which was over 24.5 million tones (FAOSTAT, 2020) representing the high amount of underused agro-industrial coproduct. Then, peach seed may be an attractive material due to its high protein content of 27% (Farag et al., 2022).

It is also important to establish the most appropriate and effective method for protein recovery, improving the extraction yield and the quality of the compounds of interest. Emergent extraction technologies have been considered alternative methods to reduce the use of organic solvents, which may contribute to the formation of lysinoalanine, an undesirable component, and also to the increase in Maillard reactions, darkening the resulting product (melanoidin) (Constantino & Garcia-Rojas, 2022). Besides, the extraction and fractionation methods also affect the functional properties of the recovered protein fraction, and help to establish good industrial uses of this fraction as a multi-purpose ingredient for food product formulations (Kahraman et al., 2022). Some relevant functional properties are hydrophobicity, emulsifying, sulfhydryl groups and foaming characteristics. These properties are decisive attributes in developing new protein-based food products, its characterization for new plant protein sources remains a challenge that must be elucidated. Different methods have been applied to extraction protein vegetable and also improve their functional

* Corresponding author.

E-mail addresses: carla.roana@posgrad.ufsc.br (C.R.M. Rudke), torres.talyta@gmail.com (T.M.S. Torres), acacio.zielinski@ufsc.br (A.A.F. Zielinski), s.ferreira@ufsc.br (S.R.S. Ferreira).

<https://doi.org/10.1016/j.foodhyd.2024.109991>

Received 18 December 2023; Received in revised form 7 March 2024; Accepted 11 March 2024

Available online 12 March 2024

0268-005X/© 2024 Elsevier Ltd. All rights reserved.

ORIGINAL ARTICLE

Evaluation of hydrothermal sugarcane bagasse treatment for the production of xylooligosaccharides in different pressures

Carla Roana M. Monteiro  | Luiz Gustavo G. Rodrigues  | Karina Cesca  |
Patrícia Poletto 

Laboratory of Biological Engineering,
Department of Chemical and Food
Engineering, Federal University of Santa
Catarina, Florianópolis, Santa Catarina, Brazil

Correspondence

Patrícia Poletto, Department of Chemical and
Food Engineering (EQA), Federal University of
Santa Catarina (UFSC), Campus Trindade, PO
Box 476, Zip Code 88010-970 Florianópolis,
SC, Brazil.

Email: patricia.poletto@ufsc.br

Funding information

CAPES-PRINT, Grant/Award Number:
88887.310560/2018-00

Abstract

Hydrothermal processing is an organic solvent-free technology capable of solubilizing hemicellulose in oligomers of interest. This study evaluated the influence of pressure (2.5 and 10 MPa) on the release of the main components of sugarcane bagasse (SCB) as reducing sugars, phenolic compounds and xylooligosaccharides (XOS) during hydrothermal treatment in a continuous flow mode for 30 min. The study carried out at 180°C showed that 85% of the sugar extraction capacity was reached after 15 min at both pressures. The evolution of pH, phenolic compounds released in the liquor and small changes in the lignocellulosic structure were also monitored and related to the effects of hydrothermal treatment. The xylose content was similar at both pressures (22 mg/g xylan), while the XOS (X2-X6) yield was 87.5 and 111.4 mg/g xylan at 2.5 and 10 MPa, respectively. A mass balance was used to estimate that 6.76 kg of XOS could be produced from 100 kg of SCB treated at 180°C, 2.5 MPa, and 15 min.

Practical Applications

Sugarcane production generates a large amount of by-products. The study aimed to use sugarcane bagasse (SCB) for the extraction of xylooligosaccharides through hydrothermal processing whose the influence of two pressures (2.5 and 10 MPa) in this process was evaluated. This process is an organic solvent-free technology that establishes a sustainable strategy for the exploitation of this material. Residues (SCB) have great potential to be explored to prepare value-added products in the food and pharmaceutical industries.

1 | INTRODUCTION

Commercial interest in functional foods has grown in recent years, mainly related to prebiotic ingredients, for example, (XOS). Their consumption has been associated with numerous health benefits (Amorim, Silvério, Prather, & Rodrigues, 2019). SCB is one of the most studied lignocellulosic materials for the production of XOS. This biomass generated from sugar and ethanol industrial plants is widely available in tropical and subtropical areas (Ruggeri & Corsi, 2019). Approximately 54 million tons of SCB are produced annually worldwide (Zhou & Xu, 2019b). Most of this waste is used to feed boilers in energy supply industries (Carvalho, Neto, Da Silva, & Pastore, 2013)

and ethanol production (Alokika, Kumar, Kumar, & Singh, 2021). However, due to its composition rich in hemicellulose (24–29%), several studies have shown that SCB is a promising raw material for the production of XOS (Brienzo, Carvalho, & Milagres, 2010; Otieno & Ahring, 2012). According to Manzanares (2020), the existing general consensus on the bioeconomy contributes to the overall economy sustainability by involving a large number of industries and services in this new economic model. One of the main strategies to make the circular economy viable is biorefining, through the closing of cycles of biomass (reuse of residues from forestry, agro, processing and post-consumption activities). Therefore, it is important to develop different studies on the best way to use these residues.

Non-thermal plasma as an efficient pretreatment to lignocellulosic raw materials

Gabriela N. Pereira¹  | Karina Cesca¹  | Maria Angélica F. Pereira¹ |
Carla Roana Monteiro Rudke¹  | Otilia Monica Alves Borges¹ |
Anelise Leal Vieira Cubas²  | Eduardo Zanella³  | Boris U. Stambuk³  |
Patrícia Poletto¹  | Débora de Oliveira¹ 

¹Department of Chemical Engineering and Food Engineering, Federal University of Santa Catarina (UFSC), Florianópolis, Santa Catarina, Brazil

²Environmental Science Master's Program, University of Southern Santa Catarina (Unisul), Palhoça, Santa Catarina, Brazil

³Yeast Molecular Biology and Biotechnology Laboratory, Department of Biochemistry, Federal University of Santa Catarina, Florianópolis, Santa Catarina, Brazil

Correspondence

Karina Cesca, Department of Chemical Engineering and Food Engineering (EQA), Campus Trindade, PO Box 476, 88010-970 Florianópolis, Santa Catarina, Brazil.
Email: karinacesca@gmail.com

Funding information

Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq); CAPES-PRINT, Grant/Award Numbers: 88887.310727/2018-00, 88887.310560/2018-00; Central Laboratory of Electronic Microscopy (LCME-UFSC) Interdisciplinary Laboratory for the Development of Nanostructures (Linden); Plasma Laboratory (LABPLASMA) for the Unisul; FAPESC

Abstract

Non-thermal plasma is an ecologically correct technique that is increasingly being explored. In this work, plasma was applied as a delignification technique for different lignocellulosic residues (brewery, banana peel, and mango seed peel). The influence of non-thermal plasma on the physical and chemical characteristics of the residues was also explored by the techniques scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), x-ray diffraction (XRD), and RAMAN spectroscopy. Delignification of approximately 48% was observed in 5 min of the process for the brewery by-product, 35% the mango seed shell, and 24% the banana peel. Small changes in morphology (SEM), degradation temperature (DSC), compositional analysis (FTIR, XRD, and RAMAN) after pretreatment with non-thermal plasma were observed. Thus, we bring unprecedented results using non-thermal plasma as an alternative pretreatment for different lignocellulosic residues, indicating an attractive technique for subsequent enzymatic hydrolysis and thus obtaining added-value products, such as bioethanol and xylooligosaccharides.

KEYWORDS

cellulose, delignification, different lignocellulosic materials, hemicellulose, lignin, non-thermal plasma

1 | INTRODUCTION

Lignocellulosic materials are found in almost all plant-derived materials, from wood, grass to agricultural waste, and solid urban waste (Yang, 2007). Some examples are banana peel, residues resulting from the processing of mango and brewery by-product. The composition of the lignocellulosic materials in the waste may change depending on the genotype and environmental conditions. This type of content is usually composed of a large fraction of cellulose (40%–50%), followed by hemicellulose (25%–30%) and lignin (15%–25%) (Biswas et al., 2014).

The amount of waste generated in the processing of bananas, for example, makes the skin correspond to 35%–40% of the weight of the fresh fruit. According to Food and Agriculture Organization Corporate Statistical Database (FAOSTAT, 2020), the Brazilian production of banana in 2020 was more than 6 million. In terms of amount, in 2018 it was generated around 2.7 million tons of peels in Brazil (Rebello et al., 2014). Mangoes, mangosteens, and guavas production reached 2 million tons in 2020 (FAOSTAT, 2020). Mango production reached 100 million tons in 2018, which generates by-products such as peel and stone, which make up between 35% and 60% of the fruit. The mango seed shell has already been used in animal feed



Trends in Dairy Products: New Ingredients and Ultrasound-Based Processing

Carla Roana Monteiro Rudke¹ · Callebe Camelo-Silva¹ · Adenilson Renato Rudke¹ · Elane Schwinden Prudencio^{1,2} · Cristiano José de Andrade¹

Received: 23 February 2023 / Accepted: 21 June 2023

© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2023

Abstract

Demanding consumers increasingly seek products with a more nutritional appeal that contribute to nutritional health. Considering the requirements of sustainable processes, natural ingredients, and healthier products, this review describes the most recent trends in dairy products, focusing on new ingredients and ultrasound technology. These ingredients include prebiotics, probiotics, and synbiotics; substitutes for reducing sugar and lipids; and natural preservatives such as nisin. Also, ultrasounds have been identified as a promising strategy for processing food products since it can increase shelf-life and enhance sensorial acceptance.

Keywords Postbiotics · Whey protein · Emerging technology · Bacteriocin

Introduction

The demand for appealing foods that contribute to well-being and health has encouraged the development of new products and new technologies. In this context, the dairy industry constantly develops and implements innovations, mainly correlated to new ingredients and emerging technologies instead of those used traditionally. Milk and milk-based products are among the most consumed foods in various meals in different countries. For this reason, they are a suitable option for

delivering new ingredients and being subjected to new technologies. Fortifying dairy products with new ingredients is a strategy accepted by scientists, food manufacturers, and consumers. Utilizing new components and developing novel dairy products create significant value for the food industry while improving the nutritional characteristics of the product. Granato et al. (2022) highlighted that, considering rising consumer demands and expectations for more nutritious dairy foods, food companies of differing sizes have invested in developing dairy foods with added ingredients that may boost consumer health, the so-called functional foods (Rudke et al., 2022).

Dairy products with nutritional and health claims, i.e., food products that have beneficial nutritional properties due to nutrients or other added substances, such as probiotics, prebiotics, synbiotics, and postbiotics, with reduced sugar, low fat, and whey protein, play an essential role in the current scenario of dairy processors. The dairy industry has new perspectives in developing novel and innovative products with added functional properties driven by the consumer demand for healthier food products. In addition to health, consumers are concerned about safe food, which is nourishing while being free from pathogenic microorganisms. Therefore, additives and new technology that restrict and eliminate pathogens are important. Among the additives, nisin is a bacteriocin (against Gram positive) that acts as a natural preservative, especially in dairy products, being the only natural antimicrobial peptide approved by the US Food and Drug Administration (FDA) for this. According

Callebe Camelo-Silva and Carla Roana Monteiro Rudke contributed equally.

✉ Cristiano José de Andrade
cristiano.andrade@ufsc.br

Carla Roana Monteiro Rudke
carla.roana@posgrad.ufsc.br

Callebe Camelo-Silva
callebecamelosilva@gmail.com

Adenilson Renato Rudke
adenilsonrudke@gmail.com

Elane Schwinden Prudencio
elane.prudencio@ufsc.br

¹ Postgraduate Program in Food Engineering, Technology Center, Federal University of Santa Catarina, TrindadeFlorianópolis, SC 88040-970, Brazil

² Department of Food Science and Technology, Agricultural Sciences Center, Federal University of Santa Catarina, ItacorubiFlorianópolis, SC 88034-001, Brazil

RESEARCH ARTICLE

Impact of front-of-pack labels in chocolate bars and soft drinks on consumer perceptions: A cross-sectional study using free word association

Rebeca Dantas Leão¹ | Maria Jaízia dos Santos Alves¹ |
Carla Roana Moraes Monteiro¹ | Talita Ribeiro Gagliardi² | Germán Ayala Valencia¹ 

¹Department of Chemical and Food Engineering, Federal University of Santa Catarina, Florianópolis, Brazil

²Laboratory of Immunology Applied to Aquaculture, Department of Cell Biology, Embryology and Genetics, Federal University of Santa Catarina, Florianópolis, Brazil

Correspondence

Germán Ayala Valencia, Department of Chemical and Food Engineering, Federal University of Santa Catarina, Campus João David Ferreira Lima, PO Box 476, Rua Roberto Sampaio Gonzaga, s/n, Florianópolis CEP: 88040-970, Santa Catarina, Brazil.
Email: g.ayala.valencia@ufsc.br

Abstract

Food packaging is a factor used to attract consumer attention and generate sensory and hedonic expectations. Most food packaging use conventional labels having the nutritional table as the main component; however, other alternatives such as the traffic light (TL) and warning labels have been proposed to the food industry as an alternative to improve the consumer interpretation related to food products. This study aimed to understand the effect of two front-of-pack labels (TL and warning models) on consumer perceptions and purchasing intention using free word association. A cross-sectional study with 551 volunteers was carried out using chocolate bars and soft drinks having conventional labels and front-of-pack labels. Results from volunteers using free word association show that front-of-pack labels did not impact the purchasing intention of volunteers when compared with food packaging having conventional labels (only nutritional table). However, the use of front-of-pack labels can modify consumer perception, inducing consumers to reflect on the information exposed on the food label. In this context, the warning label was more efficient to transmit the information to consumers when compared with the TL model. Based on these results, it is possible to suggest the warning model as the most indicate label to be used in food products.

KEYWORDS

consumer profile, food labelling, food packaging, nutritional information, traffic light model, warning model

1 | INTRODUCTION

Food packaging including labels are non-sensory factors that influence consumer expectations, increasing the opportunities for food selection and consumption.^{1–3} Conventionally, labels are used back of the package (BOP), serving as a tool to inform nutrition food composition.⁴ However, in recent years, several studies have shown that

consumers do not know how to interpret correctly food labels, leading to inappropriate feeding practices and food rejection.^{5–9}

An alternative to reduce inappropriate feeding practices and increase consumer preference is modifying labelling requirements. In this way, front-of-pack (FOP) labels have been recently introduced in several countries.^{2–4} FOP labels are logs, symbols or icons printed on food package used to facilitate the interpretation of the nutrient profile of food products. Furthermore, FOP can be used to attract consumer attention and increase intention to purchase.¹⁰

The authors declare no funding.

RESEARCH ARTICLE

Packaging Technology and Science

WILEY

The influence of packaging colour on consumer expectations of coffee using free word association

Alexia Carvalho Sant'Anna¹ | Maria Jaízia dos Santos Alves¹ |
Carla Roana Moraes Monteiro¹ | Talita Ribeiro Gagliardi² | Germán Ayala Valencia¹ 

¹Department of Chemical and Food Engineering, Federal University of Santa Catarina, Florianópolis, Santa Catarina, Brazil

²Laboratory of Immunology Applied to Aquaculture, Department of Cell Biology, Embryology and Genetics, Federal University of Santa Catarina, Florianópolis, Santa Catarina, Brazil

Correspondence

Germán Ayala Valencia, Federal University of Santa Catarina, Campus João David Ferreira Lima, PO Box 476, Rua Roberto Sampaio Gonzaga, s/n, CEP, Florianópolis, Santa Catarina 88040-970, Brazil.
Email: g.ayala.valencia@ufsc.br

Funding information

The authors declare no funding.

Coffee packaging colour is a factor used to attract consumer attention and generate sensory and hedonic expectations. This study aimed to understand the effect of colour packaging on consumer expectations. A cross-sectional study with 432 volunteers was carried out using coffee packaging with black, red, green and yellow colours. Each coffee packaging was compared with another similar coffee packaging having the opposite colour in the chromatic circle (white, light blue, pink and dark blue colours). Results from volunteers using free word association show that important attributes related to coffee could be induced in the volunteers using food packaging with black, red and green colours. Furthermore, the white colour can also be used in coffee packaging; however, this colour was not correlated with warm products as expected in coffee. Finally, coffee packaging having pink, light and dark blue, as well as yellow colours was rejected by the volunteers, suggesting that those colours should be avoided in packaged coffee.

KEYWORDS

coffee consumption, consumer profile, emotion in food, food packaging colour, sensory

1 | INTRODUCTION

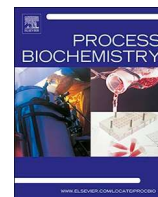
Historically, food packaging has been used to contain foods and conserve their quality, preserving them from external factors such as odours, shocks, dust, temperature, physical damage, light, microorganisms and humidity.¹ Furthermore, food packaging is used to attract consumer attention and generate sensory and hedonic expectations.²

In general, sensory attributes linked with intrinsic and extrinsic properties are the principal factors that play a significant role in the acceptance of food products.³ Food packaging can be classified as a non-sensory factor that influences consumer expectations; this is the first way to establish a relationship between the food appearance and the necessities and expectations in the consumer. Therefore, food packaging is used to influence consumer expectations, increasing the opportunities for food selection and consumption.^{3,4} According to the literature, several factors used in the food packaging such as shape, colour, image and nutritional labels could impact the consumer

perceptions and purchasing intentions.^{2,3,5,6} However, the best colour for each food packaging depends on the type of food and its presentation.^{4,7} Colours are classified as warm (e.g., black, red, orange and yellow) and cool (e.g., white, green, blue and purple), and they can be associated with positive or negative emotions, affecting food acceptance.⁸

Word association (WA) is a qualitative method based on the free listing used in food science to understand consumer perceptions of food products. In WA experiments, a stimulus is given to the respondent (e.g., images), and then they must write about the associations that come to their minds, giving relatively unrestricted access to mental representations of the stimulus. Recently, WA has been used to understand the perception of consumers regarding different foods.^{9–11} In this way, WA can be used to investigate the effect of colour packaging on the consumer perceptions.^{3,4,7,12}

Coffee is one of the most consumed beverages with a bitter taste worldwide. In this way, global coffee consumption is



Review

Xylooligosaccharides: Transforming the lignocellulosic biomasses into valuable 5-carbon sugar prebiotics

Patrícia Poletto*, Gabriela N. Pereira, Carla R.M. Monteiro, Maria Angélica F. Pereira, Sidnei E. Bordignon, Débora de Oliveira*

Department of Chemical and Food Engineering, Federal University of Santa Catarina, Florianópolis, SC 88040-900, Brazil

ARTICLE INFO

Keywords:

Xylan
Xylooligosaccharides
Hydrolysis
Food waste
Prebiotic

ABSTRACT

Xylooligosaccharides (XOS) are prebiotics derived from lignocellulosic materials presenting important functional properties. Traditional methods of XOS production often require the presence of acidic and basic catalysts for xylan extraction. However, new strategies and technologies such as hydrothermal, steam explosion, and green catalysts have been used to obtain XOS. Overall, these technologies are considered more environmentally friendly due to the lower amount of waste generated. This review summarizes the strategies used in XOS production, describing the process variables involved in xylan extraction and depolymerization, mainly for the most cited biomasses: sugarcane bagasse, corncob and wheat straw. Additionally, technical applications in the food area and future perspectives are presented. The use of hydrothermal pretreatment may be a promising strategy for xylan extraction. Besides the higher pressure and temperature, the conditions can be optimized to achieve satisfactory yields with minimal release of impurities and inhibitors. The enzymatic treatment should be combined to achieve higher yields of XOS with a low degree of polymerization, which is required for prebiotic function. Importantly, adequate knowledge of the lignocellulosic composition of biomass, particularly, the characteristics of hemicellulose chains, is needed to determine the best process conditions.

1. Introduction

The agroindustry has been undergoing a constant transformation that focuses on the recovery of by-products for the production of sustainable ingredients for food and beverages, feed and pharmaceutical industry. Lignocellulosic materials have a valuable fraction containing hemicellulose, which can be transformed into oligosaccharides composed of xylose units [1].

Xylooligosaccharides (XOS) are composed by 5-carbon sugars presenting the molecular formula $C_{5n}H_{8n+2}O_{4n+1}$, where $n = 2-6$ xylose units [2,3]. They are considered prebiotic compounds presenting technical and health claims. XOS has the advantage to be fermented by specific beneficial bacteria, as *Bifidobacterium* and *Lactobacillus*, while 6-carbon sugars, as fructooligosaccharides (FOS) and galactooligosaccharides (GOS), the best-known prebiotics, are assimilated by both beneficial and some pathogenic bacteria [4]. In addition, XOS has better potential as a food ingredient due to the higher stability range of pH (2.5–8) and temperature (up to 100 °C) [5,6]. Some other biological benefits have been reported such as immunomodulatory and anti-

inflammatory properties, anticancer activity for leukemia cells, blood sugar reducer and antioxidant activity [7]. In the food market, it is known that the purchase of functional products is a growing sector, which is motivated by the consumer conviction about the relationship between diet and health [8]. Until 2023, a total of 130 million US\$ is expected for XOS by the market of prebiotic ingredients [5], which encourages new research on production methods and new materials for high yield XOS with proper functionality.

Among the XOS manufactures, two can be cited as important key players, which were evaluated as GRAS (*Generally Recognized as Safe*). In 2013, XOS from corncob, manufactured by Shangdong Longlive Biotechnology (China), received GRAS certification based on human tests when used as a food ingredient [9]. In 2015, Longlive was evaluated by the EFSA Panel on Dietetic Products, Nutrition and Allergies requested by the European Commission, who concluded that XOS did not present any toxicity to human consumption [10]. Recently, XOS from sugarcane fiber, manufacture by Prenexus Health (USA), was also certified as GRAS for use as a texturizer and ingredient in a variety of food categories [11].

* Corresponding author at: Federal University of Santa Catarina (UFSC), Department of Chemical and Food Engineering (EQA), Campus Trindade, PO box 476, 88010-970 Florianópolis, SC, Brazil.

E-mail addresses: patricia.poletto@ufsc.br (P. Poletto), debora.oliveira@ufsc.br (D. de Oliveira).

<https://doi.org/10.1016/j.procbio.2020.01.005>

Received 25 September 2019; Received in revised form 26 December 2019; Accepted 8 January 2020

Available online 28 January 2020

1359-5113/ © 2020 Elsevier Ltd. All rights reserved.



Phenolic Compounds and Pectin-Rich Extracts Recovered from Peach Pomace by Sequential Pressurized Liquid Extractions

Carla Roana Monteiro Rudke¹ · Adenilson Renato Rudke¹ · Amanda Tavares Germano² · Luciano Vitali² · Acácio Antônio Ferreira Zielinski¹ · Sandra Regina Salvador Ferreira¹

Received: 24 June 2024 / Accepted: 17 December 2024

© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2025

Abstract

Phenolics and pectin compounds were fractionated from peach pomace by sequential pressurized liquid extraction (PLE) with ethanol and citric acid solution, and the results were compared with low-pressure methods of Soxhlet and heat stirring extraction (HSE). PLE provided higher phenolic content, low reducing sugar, and the best antioxidant potential by DPPH, ABTS, and FRAP methods. The main recovered phenolics were protocatechuic acid, mandelic acid, and vanillin, which are valuable for cosmetic, food, and pharmaceutical products. The pectin yield was 14% for PLE and 20% for HSE, with galacturonic acid content of 47% and 10.9%, respectively, suggesting application in low-calorie products. The pectin fractions showed good emulsification and foaming ability and stability, with the PLE samples presenting higher water solubility and oil-holding capacity, and lower water-holding capacity compared to the HSE sample. These results endorse peach pomace as a relevant biomass for the recovery and fractionation of bioactive compounds by innovative methods. The novel technological properties evaluated for the pectin fraction indicate promising attributes for applications in food formulations.

Keywords Pressurized liquid extraction · Functional properties · Emergent technique · Co-product

Highlights

- Sequential PLE showed promising behavior for fractionating phenolics and pectin from peach pomace.
- The main phenolics recovered from peach pomace were protocatechuic acid, mandelic acid, and vanillin.
- PLE achieved a similar pectin yield with a higher content of galacturonic acid, compared to the HSE method.
- Novel functional properties of pectin from peach pomace were evaluated.
- Good foaming and emulsion ability from PLE pectin extract.

✉ Sandra Regina Salvador Ferreira
s.ferreira@ufsc.br

Carla Roana Monteiro Rudke
carla.roana@posgrad.ufsc.br

Adenilson Renato Rudke
adenilsonrudke@gmail.com

Amanda Tavares Germano
amanda.tavares@ufsc.br

Luciano Vitali
luciano.vitali@ufsc.br

Introduction

Peach fruit is globally recognized as a specialty crop and the sixth most important fruit in the world market (Anthony and Minas, 2022). The co-product of peach juice processing is the pomace, composed of the fruit peel and pulp, representing a significant amount of underutilized agro-industrial biomass (Rudke et al., 2024). According to Faostat (2022), Brazilian peach and nectarine production reached 208,823 tons in 2022, while world production exceeded 24.5 million tons. Peach pomace represents approximately 10% of the initial fruit weight,

Acácio Antônio Ferreira Zielinski
acacio.zielinski@ufsc.br

¹ Chemical Engineering and Food Engineering Department, Federal University of Santa Catarina, Box 476, Florianópolis, SC 88040-970, Brazil

² Department of Chemistry, Federal University of Santa Catarina, Florianópolis, SC, Brazil