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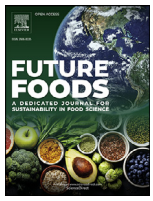

Blending side streams. A potential solution to reach a resource efficient, circular, zero-waste food system

Norbert Raak[a], Susanne Struck[b,1], Doris Jaros[b,1], Isabel Hernando[c,1], İbrahim Gülseren[d,1], Anna Michalska-Ciechanowska[e,1], Roberto Foschino[f,1], Milena Corredig[a], Harald Rohm[b,*]

[a] Department of Food Science and CiFOOD Centre for Innovative Food Research, Aarhus University, Agro Food Park 48, N, Aarhus 8200, Denmark
[b] Chair of Food Engineering, Technische Universität Dresden, Dresden 01062, Germany
[c] Research Group of Food Microstructure and Chemistry, Universitat Politécnica de Valencia, Valencia 46022, Spain
[d] Department of Food Engineering, İstanbul S. Zaim University, İstanbul, Turkey
[e] Department of Fruit, Vegetable and Plant Nutraceutical Technology, Faculty of Biotechnology and Food Science, Wroclaw University of Environmental and Life Sciences, Chelmonskiego 37, Wroclaw 51-630, Poland
[f] Department of Biomedical, Surgical and Dental Sciences, Università degli Studi di Milano, Milan 20133, Italy

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ABSTRACT

Reduction of production losses and increasing resource efficiency is needed to improve sustainability of the food supply chain. One approach to reach more resource-efficient, circular food systems is blending and processing side streams, especially when blending increases their value through compositional, nutritional or functional synergies. In this perspective we present a case study for valorizing sunflower oil press cake and whey. As the need for specialty products grows, small and medium-sized seed oil producers will be challenged with by-products. Similarly, small and geographically scattered dairy companies are faced with inadequate supply chains not allowing handling and downstream processing of whey. By combining two side streams, and applying simple processing steps and novel fermentation approaches, it would be possible not only to improve circularity of the value chain, but also to develop innovative ingredient platforms. A series of solutions appealing to various end users, from beverage producers to bakeries and snack applications, can be developed from fermented side stream blends when specific demands to ensure food safety and appropriate sensory quality are met.

1. Introduction

Reducing global food waste is one of the goals set by the UN to reach more sustainable production and consumption patterns by 2030 (United Nations, 2015). In this context, food losses refer to edible food that leaves the food supply chain during production, postharvest or processing whereas “food waste” denotes losses occuring at the chain’s end through the retailers’ and consumers’ behavior (FAO, 2011; Parfitt et al., 2010). If not reintroduced into the human food chain, typical losses are processing by-products generated during the production of vegetable oil, juice, cheese, beer, or sausages. Even though these side streams still contain valuable nutrients, they are often used as, e.g., fertilizer, biogas production substrate or, at best, for animal feed, because being unsuitable for human consumption in their current form (Raak et al., 2017).

Developing strategies to valorize food processing side streams is therefore necessary to tackle food losses and to reach more resource-efficient, circular food chains. Several projects exploiting food processing side streams for being re-used in foods have been carried out recently, e.g., BERRYPROM dealing with berry pomace (Rohm et al., 2015), ImPrOVE dealing with apple pomace (Bottu et al., 2022), VALOCAKE dealing with canola press cake (Silventoinen et al., 2022), BESTMEDGRAPE dealing with grape pomace (Perra et al., 2022), and PROVIDE focusing on oilseed press cakes as well as other streams (Smeu et al., 2022). However, in a European project recently initiated by a consortium of scientists from six European countries, the goal is to process blends of two different side streams, namely from cheese and vegetable oil production, to learn how to capitalize their synergies in nutritional or functional properties.

Whey is the main side stream of cheese production. Sweet whey is obtained at a ratio of ~3–11 kg per kg cheese, while acid curd cheese and quark production result in ~1–2 kg acid whey per kg product. Although whey composition differs depending on the process, it typically contains significant amounts of lactose and proteins. It is now state-of-the-art in large dairy companies to isolate valuable ingredients for food or pharmaceutical applications using membrane filtration (Smithers, 2015). This pathway is, however, often not available for small artisanal enterprises

* Corresponding author.
E-mail address: harald.rohm@tu-dresden.de (H. Rohm).
[1] These authors contributed equally to this work.

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Fig. 1. Different sunflower press cakes (from left to right: from fully dehulled seeds; from 90% dehulled seeds; from 70% dehulled seeds; from whole seeds; hot pressed from whole seeds; hot pressed from whole seeds and extracted with hexane).

where the whey is often downcycled to animal feed or biogas, especially in geographically remote regions. This underlines the strong need for holistic approaches and integrated solutions for whey utilization (Lappa et al., 2019).

There is an increasing production of organic oil using solventless pressing technologies, preferably at temperatures below 70 °C (Arrutiaa et al., 2020; Chew, 2020). Sunflower is the third most important oilseed crop worldwide, and its press cake is high in valuable components, especially protein and fiber. It differs from defatted meal as it contains residual oil, and its quality varies with processing history (Fig. 1). Furthermore, sunflower seeds contain 1–4 g/100 g phenolic compounds, which are only partially soluble in the lipid phase and thus remain in the press cake (Weisz et al., 2009). In spite of its potential, sunflower press cake is still underexplored as source for food.

Fermentation is a sustainable process which improves sensory and nutritional aspects as well as shelf life of foods (Tangyu et al., 2019; Terefe and Augustin, 2020). This is especially important for plant-based raw materials (Paredes-Lopez et al., 1988) where, in addition to flavor improvement, fermentation decreases the level of oligosaccharides and antinutritional compounds and improves digestibility. However, this field of research is at its infancy, and more work is needed to study starter cultures in different matrices. Despite trends towards developing novel plant-based, fermented products with increasing levels of innovation, an additional challenge is the lack of structure and texture created during fermentation.

Blending of a dairy matrix such as whey with plant materials such as press cake may represent an important strategy. Some success has already been demonstrated by mixing animal and plant proteins, which allowed to capitalize on techno-functional synergisms (Alves and Tavares, 2019; Grygorczyk et al., 2013; Roesch and Corredig, 2006). However, the needs to reduce food losses and to develop products with less refined ingredients such as press cake require more holistic approaches to reach an appropriate balance between sustainability, circularity and nutrition. The use of such materials furthermore implies that products will be richer in fiber and polyphenols, thereby affecting sensory quality. The addition of a dairy matrix containing lactose as fermentation base and whey proteins value would certainly complement the use of these novel plant bases.

In our multinational framework, we explore the potential of creating synergies between two side streams, sunflower press cake and cheese whey, and their upcycling using fermentation combined with other processes (Fig. 2), to demonstrate how to exploit the positive features of these raw materials to obtain highly nutritional and appealing new foods. The press cake provides protein and fiber, and whey contributes as water and carbon source, but also adds to nutritional quality of the entire system due to the excellent amino acid profile of its proteins (Prandi et al., 2019).

Potential research challenges are:

1 What are the effects of pre- and post-fermentation processing on the physical-chemical, sensory, techno-functional and nutritional quality of the matrices obtained, and what is the effect of the various components in imparting such properties?
2 Once the matrix has been produced, what should be the strategy to include it in new food products? Can such blends be a robust supply of new functional and nutritional ingredients?

This research constitutes a model for new approaches demonstrating the development of new platform products through “Fermentation-induced valorization of side stream blends from oilseed and dairy industry” (FERBLEND). Success using press cake from sunflower seeds will lead to further developments on press cakes from other sources, e.g., pumpkin or flaxseed. While technological removal of anti-nutritional factors such as glucosinolates, tannins, and saponins (Ancuța and Sonia, 2020) is outside the scope of this research, efforts in this area are already underway (e.g., Rudzick et al. 2020).

2. The research agenda

Six research groups from European universities collaborate in this research to unite their expertise, namely Technische Universität Dresden (DE), Università degli Studi di Milano (IT), Aarhus University (DK), Wroclaw University of Environmental and Life Sciences (PL), İnstanbul S. Zaim University (TR), and Universitat Politècnica de València (ES). FERBLEND was selected for funding as one of 12 projects in a joint call launched by SUSFOOD2 and CoreOrganic (2019) under the theme “Towards organic and sustainable food systems”.

The objectives will be reached in four work packages. In WP1, sunflower press cake and whey are gently processed either individually or as blends for microbial load reduction, material standardization, and techno-functional modification. These processes include milling and homogenization to achieve acceptable particle size, ultrasonication for fiber breakdown and microwave-assisted drying and low-moisture extrusion for increasing porosity, which might improve the fermentation process. Potential strains to be used in side stream blend fermentation were already screened in WP2 (Mangieri et al., 2022). Standardized fermentation strategies for improving sensory characteristics, increasing nutritional value and ensuring food safety are established, followed by post-treatments such as filtration, centrifugation, drying, and/or low moisture extrusion to adjust water content and to create solid, semi-solid or liquid platform products. Moreover, high moisture extrusion, homogenization or milling are applied to modulate texture and microstructure of the platform products. The fermented blends are then analyzed for composition, microstructure, rheological properties and digestibility to fully describe fermentation effects in terms of nutritional, structural and techno-functional properties (WP3). The most important and challenging WP4 deals with evaluating the potential of applying the generated matrix as a launching platform to develop novel products, which would not only be praised from their sustainable and circular quality, but also for their superior nutritional properties. Cost and life cycle analyses will be carried out to fully demonstrate the strength of the proposition.

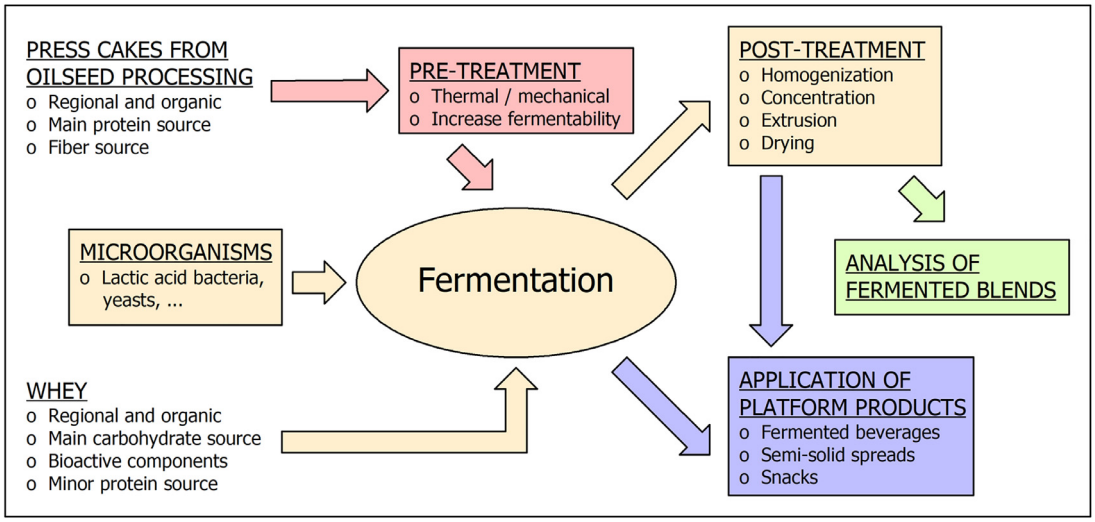

Fig. 2. Valorizing oilseed press cakes and whey in the human food chain using fermentation. *Red, workpackage 1; fawn, workpackage 2; green, workpackage 3; lilac, workpackage 4.*

3. Challenges and outlook

This research agenda is an example for the challenges coming with novel strategies for reducing food losses. Applying a fermentation process is a user-friendly, energy-saving approach that allows reaching a high level of food safety and improving sensory and functional properties of the mixtures by tuning type of microorganisms and environmental conditions. The emphasis on local, small organic producers ensures short supply chains and solves challenges related to side streams collection and economic limitations. Value will be added to processing side streams of organic agricultural products, and innovative platform products are built by taking advantage of the complementary and synergistic effects that result from blending of side streams of different origin. Improved circularity means that processing of the main product becomes more sustainable, but also that production economics are improved. By providing new processing solutions, this research will contribute to strengthening the organic supply chain, and allow providing organic labels as demanded by consumer trends worldwide. These processing solutions may be implemented in relatively small scale, ensuring a fast adoption by small and medium-sized enterprises with low capital investment needs.

While the dairy industry is more advanced and has mature solutions for side stream valorization, especially in large companies where production volumes justify the efforts, press cakes from seed oil production are still one of the most valuable but underutilized protein sources. The increased use of organic oilseeds for the production of oil specialties (e.g., sesame, pumpkin, hemp, flaxseed) is also bringing an increased challenge regarding collection and utilization of side streams due to, e.g., shelf-life issues. The targeted upcycling of press cakes prevents valuable biomass losses and will create additional value by improving the economic situation of organic seed oil producers. The higher revenue that can be created by the oil producers through marketing of both oil and press cakes will also result in higher returns for the organic farmers. Likewise, small artisanal cheese manufacturers will benefit from the collaboration with local oil producers through a higher economic value of their whey streams by reintroducing it into the food chain. Creating blends of oilseed press cakes and whey and studying the potential coming from the fermentation of such blends will provide extended, multidisciplinary knowledge necessary for the creation of an entire platform of solutions.

4. Concluding remarks

The creation of fermented blends from oilseed press cake and whey will serve as proof of concept for a new category of products to be used as platform for innovative, climate friendly foods. Plant-based milk substitutes from soaked and drained seeds are already available and highly accepted by the consumers, but their production results in a considerable amount of insoluble residues currently lost to the food chain. Future valorization by similar means would make the food supply chain more robust and provide mildly processed products with improved sensory and functional properties, while ensuring organic principles and creating new entry points for food processing side streams in novel food formulations. However, these new concepts come with additional challenges related to a lack of definition in the market and possibly some regulatory constraints. On the other hand, these products may end up being utilized as ingredients in more traditional products, and therefore help with a swift transition to plant-based diets, with little compromise by the consumer. Although this new approach has great potential, the lack of good measures and consumer communication (i.e., labeling) for products that truly meet the optimal balance of circularity, nutrition, and sustainability will limit the ability to highlight their quality attributes in the current marketplace.

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Declaration of Competing Interest

Given his role as Editor at the time of submission, Harald Rohm had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another editor, as per the

Journal guidelines. Apart from this, the authors declare no conflicts of interest.

Data Availability

No data was used for the research described in the article.

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