Proceeding Paper

Sustainable and Circular Food Innovation—The CeTA Experience[†]

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[†] Presented at the III Conference la ValSe-Food and VI Symposium Chia-Link Network, online, 15–17 November 2021.

Abstract: Worldwide, around a third of loss and waste is generated at different stages of the food transformation chain, generating relevant economic, social, and environmental impacts, and increases in the water footprint, emission of greenhouse gases, pressure on the use of arable land, production costs, and decrease in the availability of food for the population. These reasons make imperative the implementation of strategies that minimize the generation of these losses. The Chilean “Technology Center for Food Innovation” (*Centro Tecnológico para la Innovación Alimentaria*—CeTA), aware of this problem, is contributing to the development of innovative products where materials that are considered waste or by-products from processes in the food, agriculture, cattle raising, and aquaculture industry are reused, or raw materials that do not meet commercial standards, taking advantage of their properties and bioactive compounds, turning them into value propositions that have circular economy components. Examples of these products developed in CeTA include soups, fruit purees, snacks, baked products, food ingredients, and breakfast cereals that contain valued raw materials such as barley bagasse, defatted coconut flour, fruit pomaces, discarded meats, quinoa grown in lagging areas of Chile, as well as stems, leaves, and fruit and vegetable peels, thus generating an environmental, economic, and social impact.

Citation: Vivanco, J.P. Sustainable and Circular Food Innovation—The CeTA Experience. *Biol. Life Sci. Forum* **2021**, *8*, 3. <https://doi.org/10.3390/blsf2021008003>

Academic Editors: Loreto Muñoz and Claudia M. Haros

Published: 15 December 2021

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Keywords: byproducts; circular economy; food innovation; sustainability; upcycling; wastes

1. Introduction

Food loss and waste are some of the main world problems. According to FAO, 1/3 of the food produced for human consumption is lost or wasted worldwide, that is, about MM 1300 tons of food per year [1]. This generates a decrease in the availability of food for the population, loss of resources used in its generation, increased production and final costs, causing unnecessary CO₂ emissions (3.3 million tons CO₂ and greenhouse gas emissions 6–10%), wasting water resources (250 km³ blue footprint), increasing pressure on arable land, among others [2]. In Chile, for fruit and vegetable industries, 52% of the country's fruits and vegetables go to processing in 246 industries, which would produce 4.6 million tons of waste per year from this raw material [3]. On the other hand, there is a high level of undernourishment due to the tons wasted by Latin America (127 million tons/year) capable of meeting the nutritional requirements of 300 million people [4]. In Chile, the national strategic program *Transforma Alimentos* carried out a characterization of six agri-food chains of importance for the country (olive oil, apples, blueberries, plums, cherries, and tomatoes) with the aim of investigating their current and potential uses and proposing improvements to minimize losses and value generated by-products [5]. Recently, the Government of Chile launched the circular economy roadmap, whose vision is that by 2040, the regenerative circular economy will drive Chile towards a sustainable, fair, and participatory development that puts people's well-being at the center. This, through the care of nature and its living beings, the responsible and efficient management of natural resources, and a society that uses, consumes, and produces in a sustainable and conscious

way, promotes the creation of green jobs and opportunities for people and organizations throughout the country [6].

The Chilean “Technology Centre for Food Innovation” is a public-private, non-profit corporation whose mission is for Chile to become a global player in the development and production of sophisticated and sustainable foods, in line with the circular economy global trend. To accomplish this, it has three innovation centers, located in strategic areas of Chile, forming and consolidating a national network of pilot plants, an infrastructure that will allow prototyping, piloting, and scaling food innovations, adding value to raw materials and agri-food by-products.

2. Results and Discussion

A list of the innovation projects focused on circular economy and quinoa valorization that have been developed by Chilean entrepreneurs, start-ups, private companies, universities, and non-profit organizations in collaboration with CeTA, along with a brief description of each of them is shown below:

2.1. Development of Healthy Breakfast Cereal Flakes from Quinoa of Aymara Origin (CORFO InnovaChile, Code 20SN-129433)

This innovation project consists of addressing the problem of the low commercialization of Chilean quinoa by indigenous communities. This initiative was carried out by *Suma Jui* indigenous association, located in the northern Chilean village of Cariquima (lagging zone from Colchane district, Tarapacá Region), which has 33 founding partners belonging to nine Aymara indigenous communities. This project’s aim is the development of healthy quinoa-based flakes breakfast cereal with high nutritional added value: No sugar added, without warning labels for critical nutrients associated with Chilean law of food labeling and advertising, impacting this indigenous community in both economic and social terms, through a value proposition for a valuable ancient seed.

2.2. Valorization of Food Surpluses for the Formulation of Solidary and Healthy Foods in Wholesale Markets (FIC-RM, Code 40026935-0)

The sale of fruits and vegetables in *Lo Valledor* wholesale market—located in Santiago, Chile—generated around 18 thousand tons of organic waste in 2018. As a result of the recommendations of a study carried out by the *Universidad Bernardo O’Higgins* (UBO), the *Banco de Alimentos Lo Valledor* foundation (FBALV) was founded which has the aim to recover fruits and vegetables in order to give them free of charge to social organizations that provide food to vulnerable people. In the search for new solutions for this matter, a circular economy strategy in the *Lo Valledor* wholesale market is being implemented by these two entities (UBO and FBALV) in collaboration with CeTA, funded by the Government of Chilean Metropolitan Region consisting in valuing surpluses (leaves and stems discarded from the sale of vegetables and fruits, and fruits and vegetables not used by FBALV) in the preparation of sustainable and healthy foods: Soups, fruit preserves, concentrates. In this way, innovation will be promoted for both satisfying the need to expand food upcycling by means of valorizing food surpluses and the need of the social organizations belonging to FBALV to diversify their food matrix, making available healthy foods for free focused on the needs of beneficiaries.

2.3. Valorization of Barley Bagasse in the Development of Breakfast Cereals with Healthy Properties (CORFO InnovaChile, Code 20SN-151694)

The beer market in Chile has grown robustly in recent years. Barley bagasse is a by-product that corresponds to about 25% of beer production: This by-product represents an opportunity to reinsert a renewable input into a production process due to its remarkable content of dietary fiber and protein, with a positive environmental impact. Making the most of it, *Triunfo* brewery is developing a breakfast cereal with the addition of barley bagasse and healthy properties (high content of dietary fiber, non-sugar added, without warning labels for critical nutrients associated with Chilean law of food labeling and

advertising) and a circular economy component. This innovation project is contemplating the prototyping, productive scale-up, nutritional, and sensory validation of this breakfast cereal, constituting an important value proposition towards sustainable beer production.

2.4. Reuse of Grape Pomace for the Development of Healthy Extruded Snacks (CORFO InnovaChile, Code 21SEC-171242)

The wine industry is of great importance in the central region of Chile. Each year, it generates a lot of waste, such as grape pomace and seeds, with significant potential to be revalued due to its important content of dietary fiber and polyphenolic compounds. This innovation project focused on circular economy carried out by *B-Japi* entrepreneur, attends to develop a dipable healthy snack by means of the reuse of red grape pomace as a source of sustainable raw material that allows obtaining foods with healthy properties at lower costs. Thanks to the use of the microwave vacuum dehydration technology and subsequent cook extrusion, it is possible to develop a food that preserves nutritional, chemical, and bioactive properties present in the grape pomace from red wine, which may contribute to prolonged satiety, good digestive function of the intestinal tract, and protection of the bacterial flora.

2.5. Keto-Friendly and Protein Pop Dry Snacks: Remanufacturing and Rethinking the Meat Industry (CORFO InnovaChile, Code 21SEC-171153)

In general terms, the waste from slaughterhouses and other meat processing industries is used in the production of animal feed or simply discarded, which is associated with environmental problems that should be avoided. In the framework of the circular economy, considering its environmental, economic, and social aspects, this innovation project carried out by *Llawken* company will give rise to a new value proposal, based on the use of these by-products from the meat industry, creating snacks low in available carbohydrates (keto-friendly) using an emerging and sustainable technology, such as vacuum microwave-assisted dehydration (also known as “pop drying”), which has the advantages of maximizing the nutritional quality of the product and its sensory characteristics. The development of a recyclable packaging that has oxygen, light, and moisture barriers will also be carried out.

2.6. Upcycling in the Fruit and Vegetable Industry: Healthy Snacks Based on Discarded Vegetables (CORFO InnovaChile, Code 21SN-182583)

“The Imperfect Project” Chilean start-up is an initiative that seeks to generate reuse (upcycling) of fruits and vegetables that do not meet some commercial quality standards required to sell it as is and/or its agri-food by-products, in the development of new food products for massive consumers, such as snacks and cereal bars, maintaining their healthy properties. This would make it possible to face problems associated with overweight and obesity in the population caused by processed foods, taking into account that post-COVID19 data show a growth in world consumption of this kind of products. It is an innovation project with environmental, social, and commercial impact, focused on a powerful and growing snack market.

2.7. Healthy and Sustainable Extruded Snacks Based on Local Legumes, Plants, and Fruits (CORFO InnovaChile, Code 21SNM-156926)

The robust growth in the snack market category in Chile allows the generation of opportunities for *Verax*—a women’s entrepreneurship—to develop new food products in this category with a focus on a healthier diet in comparison to most of the snacks available in the market, using local raw materials such as fruits, vegetables, legumes, and apple fiber. The latter is a by-product obtained from the processing of this fruit, constituting an important proposal for the revaluation of resources with a positive environmental impact. That is why the final objective of this innovation project is to develop a portfolio of extruded snacks free of warning labels for critical nutrients associated with Chilean law of food labeling and advertising, with the addition of pre and probiotics, with healthier properties

for the immune and digestive systems than conventional snacks, and a circular economy component. The project focuses on prototyping of the products and packaging, scale-up, as well as nutritional and sensory validation.

2.8. Valorization of Defatted Coconut Flour By-Product to Develop Healthy Breakfast Cereals (CORFO InnovaChile, Code 21SN-182567)

The increase in awareness in relation to health and integral well-being has generated more informed consumers who are interested in eating good, nutritional, and healthy quality foods. Due to this new trend, the sale of products such as coconut fat—used for both culinary and aesthetic purposes—has increased, generating a great quantity of by-products associated with its production. This innovation project is carried out by a Chilean company *Nutrisa*, under the frame on the need to generate a circular economy-focused product by using the defatted coconut by-product flour (rich in dietary fiber) in an optimal, innovative, and beneficial way, giving it added value by incorporating it as an ingredient with high nutritional properties to develop a healthy breakfast cereal with differentiating and striking attributes for current consumers such as two products obtained through the cook extrusion process, one with antioxidant properties and the other with probiotics, products to which novel flavoring systems will also be applied.

3. Conclusions

The food development and innovation initiatives supported by CeTA contemplate co-creative work with the entrepreneurs and beneficiaries of the projects from the idea detection based on a problem or opportunity, diagnosis and review of the state of the art, creation of the business model, to then execute the development stages of the product(s) through ideation stages, concept product tests, application and small-scale prototype execution, scale-up at a pilot plant level, safety, nutritional and sensory issues, in addition to being profitable value propositions that contemplate environmental impacts with circular economy components and upcycling of food by-products and waste.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: Author thanks Ia ValSe-Food-CYTED (119RT0567) grant for the invitation to present this work.

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