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Operationalizing circular economy. Reflections on a by-product upcycling value chain construction in the brewing sector

RESEARCH ARTICLE

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Abstract

The concept of a circular economy has arisen in response to the problems related to the limits of the dominant linear economic system in contemporary societies and of the finite resources of our planet. The transition from waste status to a raw material by reusing it makes it possible to modify its value for future users and thus to redistribute this value. This article focuses on the case of spent grain to illustrate the role of the circular economy in food transition. Bases on a series of interviews, the paper discusses business modeling to operationalize sustainable development in the food sector and presents a discussion and conclusion on the advantages and limitations of the deployment of the circular economy in the brewing industry, taking into account and understanding the interests and constraints of various stakeholders.

Keywords: circular economy, by-product, sustainable development, upcycling, brewer's spent grain
JEL codes: L23, L21, Q01, Q56

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1. Introduction: food and the circular economy

The implementation of a circular economy is based on a stable economic system guaranteeing the reuse of materials such as biowaste with a view to achieving convergence between economic and environmental performance (Fercoq, 2014). While some research shows a certain convergence (Antheaume and Boldrini, 2017), it comes up against sociocultural, legal or organizational obstacles in the project implementation phase.

However, the agrifood industry is still poorly represented within the institutional framework of the circular economy. While its standards can be transposed in the same way as for any other economic sector, issues related to food production require special treatment, particularly with regard to economic burden, public health, territorial development, environmental impacts and consumer perception/acceptance. Indeed, there are strong constraints and specificities inherent in the agrifood sector, essentially linked to the seasonality of production and consumption, the perishability of agricultural products and the variability of their yields due to climatic hazards (Notarnicola *et al.*, 2017). These constraints have a strong impact on the organization and on the location of productions and transformations. Thus, in value chains, the adoption of technologies that facilitate sourcing and processing is a major issue. The application of these technologies determines the organizational modalities through industrial standards that ensure coordination among actors. The actor who is able to enforce a standard, or control the global level of quality, is often in a strong position and manages the entire food chain (Jacobides and Winter, 2005). The circular economy approach in the agrifood sector is therefore limited, on the one hand, to organic waste recovery from a market diversification perspective and, on the other hand, to addressing food waste from an economic and social sustainability perspective (Rousselière *et al.*, 2022).

Substantial upgrading must take place to limit the biosphere withdrawals flows entering the system and produce less waste that leaves the system (Braungart *et al.*, 2007; El Hagggar, 2010; Niero and Hauschild, 2017). This article focuses on the case of spent grain, in Nantes and Québec basins.

After a literature review on major challenges and issues of the circular economy in the food sector, the case of the brewing sector and the methodology bases on semistructured interviews will be presented. The results section focuses on brakes and levers for operationalizing the circular economy with spent grain. and the discussion the discussion sheds light on understanding the interests and constraints of various stakeholders thanks to the synthetic contribution of a business model built on the basis of the material collected during the interviews.

2. State of the art

The circular economy is frequently approached from the point of view of waste management of upstream economic actors on the one hand and from the perspective of supply and demand and the behavior of downstream economic actors on the other. An entry into the circular economy can involve a reflection on the use and consumption of upcycled resources while simultaneously taking into account the organizational, economic and managerial issues of the actors who generate resources previously considered waste. Indeed, the consumption of 'ex'-coproducts can be considered a virtuous and responsible mode of supply, aiming to ultimately meet the expectations of a user of the finished product or not, whether he or she is the final consumer or an economic player further down the value chain. In all cases, the finished product must be of global quality to an equivalent finished product made from nonrecycled raw material. This product must therefore respond to issues of conventional quality and better environmental impact and even social performance. This product from a circular value chain is therefore more eco-efficient than a conventional product. This is the case, for example, for products with an extended product life produced through more efficient sorting, better equipment maintenance, repairs or donations. It can also be achieved through the substitution of products by others, requiring less material or energy for its production or use, an eco-designed product, or the replacement of a product with a service. Another type of practice concerns the reduction of consumption: reduction of acquisitions, reduction of superfluous purchases, reduction of uses, reduction of

the frequency or quantity of products used, and reduction of rejected products by avoiding waste. Exchange or sharing measures associated with cooperation or pooling, self-production, reduction of intermediaries or actors in a value chain, with the aim of reducing the stages of transport, can also be targeted. These reduction behaviors are associated with principles of moderation, technology transfer, and even decreased consumption.

By optimizing the consumption of resources and minimizing discharges, the application of the principles of the circular economy to production-distribution systems results in the reduced flow of matter, water and energy. Its corollary effect is the redesign of the life cycle of a product 'from cradle to cradle' (Desvaux, 2017). To reinforce the idea of closed loop production and consumption systems, tools for measuring, analyzing and optimizing material flows can be used to upcycle waste into new resources (Piña and Martínez, 2014). To complete the flows, waste management takes on particular importance because it allows, via recovery policies based on the '5 Rs' (Reduce, Renew, Replace, Reuse, Recycle), to limit the need for natural resources (Lanoie and Normandin, 2015). However, the circular economy is not just about closing a loop and organizing a reverse supply chain to recover waste. Indeed, circularity modifies the value attributes of products, upsets the mechanisms of creation and distribution of value and can cause major strategic, organizational and cultural changes. In its broad understanding, the circular economy must take into account the protection of the environment and living organisms by preventing the emission of toxic substances. This principle is called sealing. Intensification then makes it possible to dematerialize products and services to increase the productivity of the resource by limiting the need for necessary resources. Finally, the functional economy makes it possible, by substituting the sale of a product for the sale of its use (Mont, 2002), and by promoting only the necessary adequacy between supply and need, to limit the consumption of resources while satisfying the needs of users. Finally, the last step consists of decarbonizing or producing energy with less fossil carbon, developing renewable energies and controlling energy consumption.

The circular economy therefore sets itself the objective of increasing the profitability of an economic activity (McDonald *et al.*, 2016). Advantageous for all and potentially leading to customer loyalty, this production model can allow companies to stand out in a market in constant tension due to the volatility of the price of resources. Based on the fundamental principle of the sustainability of societies, its implementation is based on the search for a system with looped circulations, which maintains a stable use of matter and energy. The deployment of the circular economy must also include social and political dimensions, taking into account the expectations of different stakeholders and their practices. However, questions about the real impacts of circularity, the keys to distributing the value of resources, the organizational capacities of companies and the cognitive frameworks of actors are still relevant. Very virtuous in theory, the circular economy model is slow to be deployed compared to other economic models. This latency could be due to the potential 'rebound effects' that can be generated when the initiatives are operationalized (French Local Authorities Association, 2020). On the other hand, more fundamental limits can be linked to the substitution of resources or to the entropy of recycling. The model must now be enriched with more sectoral case studies.

Our study therefore focuses on the operationalization of the circular economy. It seeks to understand the implications of the implementation of the circular economy in the food industry by identifying the brakes and levers that would persist for the different actors involved.

Breaking with the current linear vision of food value chains and seeking to complete the nutrient cycle, two types of resources must be used according to the French Transitions Agency: human excreta (urine and nutrient matter) and organic waste or 'biowaste'. A study (Desvaux, 2019) identified four levels of action to limit losses:

1. make public establishments examples of excreta recycling;
2. install excreta collection equipment;
3. structure a sector for agricultural recovery of human excreta in the territory;
4. recycle biowaste.

This study examines the fourth lever of action. The management of biowaste produced at each stage of the food chain is essentially linear. Companies that produce a large quantity of biowaste have an obligation to sort it and have it recovered in suitable channels (Albert *et al.*, 2018). The thresholds have been gradually lowered; today, the requirement applies to professionals producing more than ten tons of biowaste per year (Bletzacker *et al.*, 2009). Restaurant owners are struggling to comply with this regulation, and this threshold remains high. Organic waste constitutes a quarter of household waste, or approximately 150 kilograms per year and per inhabitant. The vast majority are incinerated or landfilled, and the nutrients they contain are lost (Redlingshofer *et al.*, 2019). Circular management of biowaste is still insufficiently generalized.

In France, food waste represents 10 million tons of waste per year, with a commercial value of 16 billion euros (Rollot and Rebois, 2014). However, the use of natural resources and the associated greenhouse gas emissions could be limited/avoided (Fooddiver, 2019). Upcycling is a strong trend in the circular economy and is more generally part of the process of sustainable development. Its ambition is to preserve the environment and ecosystems by reducing waste and saving energy and raw materials based on the operationalization by all stakeholders in society: companies, associations, citizens, consumers, etc. Upcycling also seeks financial savings by saving energy and materials. Today, the development of this process is still very limited on an industrial scale.

In recent years, the use of the term '*recycling*' has intensified, but the terms '*overcycling*' and '*upcycling*' in French appear in the mainstream media, indicating the intention to release more value from the subsequent reuse of a material stream previously considered a coproduct. The very meaning of '*upcycling*', which literally means '*to recycle upward*', gives an indication of *better*, connoting a product or a service of higher value than the original coproduct. Whereas recycling results in a product of lower or equal quality to that of the original product, upcycling reflects the intention to add value to the product obtained. In addition, another difference comes from the recycling process. This usually includes a step of chemical restructuring of the materials, while upcycling uses the raw products, thus saving processing energy. Recycling therefore extends the life of the product, while upcycling gives it a new life. However, recycling and upcycling have in common their preservation of the environment.

In the food industry, associations such as the Upcycled Food Association¹ (UFA), in co-construction with governments, universities, industries and NGOs, promote the concept of '*upcycled food*'. One way to formalize this concept or make it operational would be, for example, the development of a label, which could be affixed to product packaging. Similar to other labels (such as clean labels or environmental labels), this label would help the consumer choose a product by highlighting the attributes of '*upcycling*' to increase the recycling economy. This market seems to benefit from considerable growth potential in the food sector, as 39% of consumers currently want to buy foods and drinks containing upcycled ingredients, and 57% plan to buy more next year (De Ketele and Roegiers 1991). Upcycling therefore responds to strong consumer demand in terms of sustainable development.

Today, companies collect and process spent grains, mainly into energy but also into products for human consumption. This deposit can therefore be '*upcycled*' and transformed into finished products, such as snacks, cookies, granola or chips. Resources previously considered biowaste, such as coffee grounds, *ugly* fruits and vegetables, and spent grain, can now be considered a raw material that creates value for subsequent consumers.

Tackling sustainability in commercial relations between actors has strong organizational repercussions (El Ouardighi, 2008). It requires value-based management and implies a redistribution of responsibilities. Value is embodied in business relationships, the effects of which can be measured by qualitative and quantitative variables (Fabbe-Costes, 2002). With the rise of sustainable thinking in management science, the conventional understanding of business models such as the business model canvas (BMC) (Osterwalder and Pigneur, 2010) has appeared not to be completely fitted to sustainable business modeling. Indeed, it tends to focus

¹ <https://www.upcycledfood.org/>.

primarily on customer value (Bocken *et al.*, 2013), while sustainable thinking requires the consideration of a wider range of stakeholders. A new vision has therefore emerged, incorporating sustainability into the conventional understanding of business and leading to a conceptual transformation of business models. In the context of this literature review, the following section seeks to test the theoretical proposition for integrating sustainability into the understanding of the company by relying on the construction of business models that take into account a wide range of stakeholders.

3. Methodological approach

Considered producers of biowaste, breweries are responsible for the grains they produce until their final disposal or recovery, under penalty of sanctions. This legislation applies to those breweries considered large producers of biowaste. Since 2016, breweries that produce more than 10 tons of brewer's spent grain per year have been obliged to 'sort at the source', with a view to organic recovery or separate collection. The obligation that applies to all producers of biowaste, regardless of their level, breweries included, as well as all communities and individuals, was announced for 2025. However, with the circular economy package adopted in the EU in 2018, and quite recently transposed to the French level, this obligation should be in force beginning in 2023.

For the past ten years, in France, as almost everywhere in the Western world, a considerable increase in the number of micro- or small breweries has been observed, concomitantly with the evolution of consumer demand toward more diversification, naturalness and authenticity of products. The number of breweries in France thus increased from 1,023 units at the end of 2016 to more than 2,000 units at the end of 2019. The Nantes Basin has followed this trend and now has more than thirty breweries. This strong growth in the sector has raised new problems, particularly regarding spent grain valuation. The recovery of brewer's spent grain responds to two national objectives: the recovery of organic matter and the fight against food waste². This recovery effort helps meet the challenges of the circular economy and food transition. New technically and legally feasible but also economically and environmentally viable recovery paths should meet the challenges of food waste and the policies promoting a circular economy. The case of brewing spent grain is described in this article to illustrate a pathway to value creation for an agrifood by-product from a circular economy perspective.

Querying someone who has information is often a great way to access the information yourself. During a series of interviews, information about our research subject was obtained. This method of oral data collection relates to facts or representations (Baumard, 2007). The 26 individual interviews in the series, 'intended to collect, in the perspective of their analysis, discursive data reflecting in particular the conscious or unconscious mental universe of individuals' (Baumard, 2007), allowed us to complete a preliminary documentary study to better understand the study context.

The selection of interviewees was determined based on the objective of our study. Within the value chain studied, experts have been appointed and served as advisers. Within the limits of everyone's availability, we have therefore chosen to interview players in the brewing sector representing organizations of all sizes, all geographic representations, and with the most diverse activities possible to provide a representative portrayal of the profession. Some stakeholders involved in the value chain studied, such as the association of microbrewers in Quebec or the brewer's association of Pays-de-la-Loire, were also interviewed. Our list is therefore representative of the different functions of the spent grain production chain. These interviews, which lasted approximately one hour, took place between May and October 2019 (Supplementary Table S1).

At the stage where we had chosen to conduct interviews, the degree of development of our hypotheses was low. As a result, we used 'semistructured' interviews as recommended in De Ketele and Roegier (1991). This choice made it possible not to compel the interviewee and not to lead him or her to a preconceived idea of

² French environmental code.

the brakes and levers for the revalorization of brewing grains. This method gives the interviewees a certain freedom to express their conception of the feasibility of using spent grain in human nutrition. Compared to open interviews, semistructured interviews are generally shorter and more efficient in obtaining the information sought. The main open questions submitted to the interviewees were expressed, on the one hand, around their 'business' vision of the brewing sector and, on the other hand, around existing or potential practices to revalue the spent grain in human nutrition. Finally, they were asked to speak about the brakes and levers accompanying these practices and the involvement of other actors. Each of the players in the value chain interviewed was asked to give their point of view on the potential of the spent grain and to formalize any wishes for change on this subject. Although we used an interview guide, the questioning and the interview schedule were adjusted on a case-by-case basis because each individual interviewed is unique (Stake, 1995). This guide was completed, adapted, and modified iteratively as the interviews progressed.

The corpus made up of the entire speech of the interviewees was coded and then analyzed using the IRaMuTeQ tool. IRaMuTeQ (for 'R Interface for Multidimensional Analyzes of Texts and Questionnaires') is free and open software for analyzing textual data or textual statistics that works in interface with the R language. It allows statistical analyses on text corpora and on individual/character tables based on the Reinert classification method (hierarchical classification descending on a table crossing solid forms and text segments) (Reinert, 2015). IRaMuTeQ is based on the free R language and the Python language. It is developed within the Laboratory of Studies and Applied Research in Social Sciences (LÉRASS, University of Toulouse) and supported by the LabEx 'Structuring of social worlds' and is distributed under GNU GPL v2 license. IRaMuTeQ represents an alternative to the proprietary Alceste software. Both makes it possible to extract classes of meaning, made up of the most important words and sentences, and the classes obtained represent the dominant ideas and themes of the corpus. The results are sorted according to their relevance and give rise to graphical representations and analysis reports.

4. Results

Among the 26 interviews, 22 texts were analyzed for reasons of data homogeneity. A total of 2,600 text segments were processed by the tool, 90.77% of which were analyzed using a simple classification to optimize the sensitivity settings of the software. For comparison, a dual classification was also implemented, and the results were similar. The results obtained using IRaMuTeQ, that is, the number of word classes, their composition and their distribution according to the profile of the respondents, informed us about the point of view of brewers and stakeholders on the revaluation of the spent grain and its implications. In the end, four classes of words were analyzed, which is quite weak and may require a subsequent manual analysis of the content of the speech. The first of these classes, which contains more than a third (33.2%) of the segments analyzed, contains the expression *spent grain*. This class describes the agricultural world, which therefore today seems to be the predominant link to the valuation of the spent grain. It includes words such as farmer, cow, breeder, goat, cattle, animal, and donate. This class is mainly associated with breweries located in rural areas. We also note that for this valorization of the spent grain, the donation is the process in which the brewers move grain to the farmer or vice versa. Both cases have been encountered. In some cases, the farms, brewing and agricultural, are even nearby.

Then, a second class is defined, very close to the first in the sense that they are nested and where there are interrelations between them. This second class represents 17.4% of the classified segments and contains words such as owner, decide, regulation, think, world, company, Mapaq, speak, and pay. This class could represent the world of decision-makers and the possible alternatives to donating spent grain for animal nutrition. It describes how the different management scenarios for spent grain, excluding animal feed, represent alternatives to assess and study, which are subject to strategic decisions because they are highly constrained. Constraints include the cost of collection when it is a question of having the grain removed by the companies for reprocessing of biowaste under contract with local communities (Sanimax in Quebec or Veolia in France, for example); the very short deadlines because of the odor nuisance in the neighborhood caused by spent grain when it degrades; and the lack of space to store spent grain in urban areas, where

rents are particularly expensive. This class seems to be mainly associated with Quebec breweries among those who were interviewed. One could imagine that it is because of a higher real estate pressure exerted on urban breweries in Quebec or because more urban microbreweries were visited in Quebec, despite the fact that the corpus processing software should allow us to eliminate this kind of bias. In addition, the graphical representations given by IRaMuTeQ seem to show that, in the case of two separate persons, this decision is made independently by the manager and the brewer. It appears that in these structures, perhaps due to the culture of the brewing environment or due to the small size of the craft breweries, strategic decisions concern both the tactical players who manage and operational players who brew.

For the vast majority of interviewees, the current fate of the spent grain is not a waste. This remark was sometimes made spontaneously, by the brewers who bring the grain themselves to the cattle and noting the important value of this raw material to many species (some brewers described whole herds of cattle or goats recognizing the van delivery and rushing toward it) or even more indirectly, by indicating that using the spent grain for human nutrition would reduce the need for more crops grown for fodder. In addition to the declaration of the value of the spent grain, none of the interviewees spoke of ultimate waste, incineration or landfilling of this by-product. This is due to the geographic representation of our study. In both Quebec and France, recent laws prohibit the disposal of biowaste, which must inevitably be recovered, in the worst case in energy flow.

Then, two word classes that are more disconnected from the previous classes; these word classes seem less directly concerned with the theme of the grain. They probably represent the business aspect of the brewers interviewed. The first of these word classes is fairly representative of the classified segments since it includes 29.1% of them. It is characterized by very technological terms such as tank, sugar, CO₂, fermentation, brewing, cooling, enzyme, cold, temperature, extraction, pump, cycle, etc. This class seems more correlated with the brewers interviewed from Quebec, indicating that they are more professionalized than French brewers today and suggesting that they are one step ahead in the evolution of the brewing sector. Indeed, their transition to more artisanal structures, both smaller and of higher quality, occurred a few years earlier than across Europe and, more precisely, France. The brewers are perhaps quicker to gain competence in Quebec and express themselves more readily on the unit operations involved in their manufacturing processes and the link with the type of product and its overall quality. Furthermore, this class is correlated with the largest brewery sizes. Unsurprisingly, the hypothesis that the smallest structures are the most artisanal and the most recent can be proposed. Some brewers were in their thirties or forties and had abandoned a first job in favor of work as brewer in a search of meaningful work and a sense of authenticity. For these brewers, who are younger in the profession and have not necessarily had specific training, a rise in skills, reflected in jargon and a technical vocabulary, will occur over the years of experience. This word class can also illustrate a major constraint of the brewer's profession and therefore technological elements to take into account to revalue the spent grain after its production, simultaneous with that of beer. At the same time, these constraints must be studied in the case of a revaluation of the spent grain, in connection with its potential food quality as well as its standardization, according to the type of beer brewed, the brewing process, etc. For industrial use, a raw material with consistent characteristics and properties as well as availability will be sought and preferred by potential customers, as is conventionally the case for the food industry. In addition, all this technical language illustrates a cognitive brake mentioned by several brewers. Even with the proven potential value of the grain, these actors do not see themselves seizing this advantage because they do not consider it a core business activity. In addition, we can imagine that for some, the recent interest in the use of spent grain implies an unstable economic environment for the product that is not necessarily remunerative, and given the limited human resources, little time is given to tasks outside the brewing process itself.

The last word class represents 20.2% of the segments analyzed. It is characterized by geographic or relational terminologies such as Loire, country, association, and network and seems to designate both the geographic network of breweries and their network of stakeholders. These stakeholders include upstream actors, such as growers of hops. Indeed, this profession is being restructured in the different territories studied under the effect of the intensification of demand. In addition, there is real pressure on the hops market because it

was still recently controlled by seed companies that exercised considerable power over hops users due to the patents imposed on the varieties. Today, the ‘neo-hoppers’ are happy to restructure through professional associations. They therefore benefit from technical, cultural, commercial and communication, representation and image support. Finally, the players in the professional brewing associations who have been interviewed intervene. Both Association of Microbrewers of Quebec and French Association of Independent Brewers seem to have developed and diversified missions, but also acted on their negotiation capacity.

Finally, with regard to the correlations of the variables between them, the most important phenomenon to note is that of the restaurant or brewery activity, which is linked to the territory of Quebec. This coactivity, albeit initiated over a hundred years ago by a French group, is today much more heavily imbedded in Quebec. Brewpubs, neighborhood microbreweries, restaurateurs-brewers, and brewery farms are much more represented in Quebec. A large majority of microbreweries offer a range of restaurants, more or less elaborate and diversified, but with the beer most frequently prepared on site using fresh, local, quality products. While in France, tradition and habits conceive of beer as more of an aperitif at the bar with friends or colleagues, in Quebec, it is customary to snack on something at the same time as you taste a beer. However, this model now seems to be spreading in Europe, where quality takes precedence over quantity, with the development of consumer demand for healthier food.

For these operating models, even for very small volumes brewed, the number of employees immediately increases. For small breweries in the Quebec suburbs, which are well established in their neighborhood and do not exceed 600 hectoliters per year, a staff of thirty employees can be reached. Almost all of these breweries have already introduced spent grain on their menu, whether in granola in desserts, in breeding of meat or fish, in burger buns, in roasted accompaniments, etc. However, the volumes of spent grain needed are tiny compared to the quantity produced. Thus, brewers should look into pooled collection and treatment solutions for spent grain, with the production of intermediate products such as flour with several particle sizes, more or less toasted granola, or ‘milk of spent grain’. Alternatively, they should consider the use of spent grain for a food purpose in addition to an already existing use, such as animal nutrition or composting.

Table 1 summarizes all the brakes and levers identified using the interviews for the value chain. This information illustrates the very diverse and multidisciplinary types of skills, information and resources to be mobilized for future projects to revalue by-products of the food industry in human nutrition.

In this article, the question addressed by the semi-structured interviews and their analysis by IRaMuTeQ is that of the obstacles and levers to the implementation of the circular economy in the brewing sector. But in addition and in order to link different works of a collaborative research context (2-year project), a business model is proposed based on field elements (interviews, discourse analysis). This business model has been put in place by some of the brewers interviewed. As at this stage it does not benefit from an in-depth hindsight, the article is not entirely focused to it, but it is nevertheless an interesting guide for discussion. Supplementary Table S2 shows the value proposition of a circular valorization of brewer’s spent grain. The need is great for the emergence of a new actor in the agrifood value chain to link between producers and users of spent grains while taking into account the expectations of the various stakeholders and their practices. For all the products identified, the common and major obstacle lies in the reorganization of market actors and their capacity to carry out the activities required by spent grain valuation. The mission of a new economic actor who is responsible for spent grain is to take care of the spent grain collection and logistics, in a synchronized manner with the brewing process, as small breweries that are voluntarily involved do not necessarily brew every day and on a regular basis. This actor is therefore in charge of the transport, storage, stabilization, and subsequent marketing of spent grain. To this end, without necessarily building a downstream production tool, a simple shared workshop could be sized to process the deposit of 10 tons of spent grains available in the Nantes basin (within a radius of approximately 20 or 30 kilometers) each week. Then, the identified need is to find potential users of stabilized spent grain using their own production tool for spent grain valuation. The spent grain product (flour, for example, and the different possible steps of milling involved) could be used as a raw material in many industrial, semi-industrial or even artisanal products in the region. Particular

Table 1. Brakes and levers for spent grain valuation in human nutrition.

Constraints	Associated quotations	Further research needed
Regulatory	We would need another license to do the restoration We must value our biowaste via specific sectors because it is forbidden to bury it in storage centers	Bibliographic synthesis
Technological	BSG is very unstable. It ferments very quickly. The smells are really unpleasant for the residents We dry them in our oven to extend their life	Technico-economic feasibility analysis for BSG differentiated scenarios in human nutrition valorization
Geographic	Downtown, I have no place to store the BSG Our possibilities of BSG valorization are limited in urban areas Downtown, we have to pay for the removal of the BSG by a company that works with the city Breeders do not want to come here	Scenario: creation of local valuation chains
Cognitive	I cannot do it; it's not my job I already have a job We have an interest in keeping this path of valuation (purchase price and large tonnages)	Focus groups
Economic	Our activity started very recently; we are not able to invest We can invest the amount that we currently pay We would have to be subsidized by the city It is a means of valorization with low added value	Technico-economic feasibility analysis for BSG differentiated scenarios in human nutrition valorization
Environmental	We must limit the consumption of water and energy	Extended LCA
Societal acceptance	It stinks for the neighbors I transport directly to the breeder. It's heavy The cattle love it (BSG)	Focus groups
Temporal	As we have just started, we are completely dedicated to our brewing activity	Focus groups

care must be taken in the fine construction of the possible economic model(s) to offer a competitive price because acceptable value sharing at all stages of the value chain has to be demonstrated as a condition for value chain sustainability (Paillard *et al.*, 2009). Determining whether to communicate to the final consumer the inclusion of spent grain in the finished product also remains to be determined. Likewise, subsequent work should study which equipment is required for spent grain stabilization as well as potential funders for the implementation of such a collaborative scenario.

5. Discussion

The circular economy, faced with environmental and social challenges, can be both stimulated and curbed by regulations. As it embodies a business model in which creativity makes it possible to go beyond the horizons currently explored (Rey-Valette *et al.*, 2006), the circular economy is based on proactive initiatives by actors who anticipate the arrival of new regulations. Here, in the example of spent grain, the regulations on the obligation to recover biowaste both in France and in Quebec, Canada, encourage brewers to seek new ways of recovering their coproducts. On the other hand, the spent grain can no longer be wasted, that is, incinerated or buried (final disposal).

In addition, despite their ambitions to reduce environmental impacts, the practices linked to the circular economy nevertheless generate remaining questions as to their real and generalizable benefit, particularly concerning cooperation or pooling initiatives, for which risks of impact transfer or rebound effects are cited. There are therefore obstacles to these changes in practice. These brakes can be economic on the one

hand but also cognitive. Faced with a change in paradigm, the development of inertia linked to a feeling of helplessness in the face of multiple challenges is often observed.

However, levers push companies to turn more to these models, including the personal convictions of the manager, the search for new markets while standing out to customers and the prospect of future regulations (Lanoie and Normandin, 2015). These levers of action can be the responsibility of the actors in the value chain themselves but also of their stakeholders, such as public authorities or even consumers. The adoption by the various stakeholders of an approach to implementation is necessary to go beyond the stage of information sharing, which results in changing visions but not practices. It is therefore necessary to cooperatively build new collaborative solutions (Fabbe-Costes, 2015). To this end, it is possible to re-examine the contributions of the different actors to the value of the product. This value is material in terms of the availability of resources and prioritizing the intrinsic value of the products rather than their number, and it is also human, as it takes into account the working conditions and time required for the production of the products as well as the impacts generated by their consumption (Fabbe-Costes, 2015).

A limitation lies in the fact that only actors downstream of the production, transformation and distribution chain of spent grain have been heard for the most part, such as producers (brewers) or their stakeholders. However, currently, the market for the revaluation of spent grain is not yet structured, and the downstream actors were not identified before the launch of the project, and they did not answer our call as quickly as the brewers. However, the downstream were then invited to creativity sessions aimed at identifying new scenarios for the use of spent grain in human nutrition. This design thinking study will be published separately as part of our current project.

Another limitation lies in the fact that the case of large volumes of spent grain and large groups of brewers is not described. We were unable to meet with a multinational or a large brewing group, such as Heineken or RJ. However, we know that today, these breweries have solutions for their grain. More often than not, this coproduct is stored in large containers outside, then sometimes collected directly by animal nutrition cooperatives, sometimes by companies specializing in the logistics of spent grain in animal nutrition. The grains are then ensiled or transformed into granules and then sold on a dedicated, very dynamic market, the costs of which are determined as for any other cereal, according to the prices of agricultural materials.

The study shows that one route to the success of spent grain upcycling initiatives lies in the multiplication of value creation channels and therefore of business models that involve joint activities. For example, for a structure handling small volumes, one could imagine a facility directly adjacent to a brewery for the production of raw materials. The establishment of a new actor in the chain of actors (the 'grain feeder') can rely on the logistics activity of collection, in addition to the stabilization and processing of spent grain. The development of a sector therefore requires structures that can handle large volumes to achieve economies of scale, which could then lead to a production process in which human food may not be the only possible end. This player will therefore be a producer of spent grain products targeting different markets, such as human food, animal feed, cosmetics, furniture, and construction. In the case of a small-volume activity, the use of spent grain can be considered a complementary activity to that of beer brewing. For these small volumes, the models that create value are based on a business model that relies on the co-development of activities, such as a combined brewery and bakery. Alternatively, an association with linkage, awareness and prevention activities could be developed with a wide variety of audiences, ranging from economic players to the general public.

In a highly constrained framework, a structural change in the modes of production, distribution and consumption of a coproduct such as brewer's grain will necessarily involve all the players in the valorizing chain but also in society. Thus, the major challenge of the circular economy lies in the alignment of all the actions implemented throughout the product's entire life cycle. In this regard, it has already been shown to what point the management of uncertainty and complexity is a determining element because it is necessary to find

individual and collective compromises, or at least prospective solutions that satisfy a minimum level of all the players involved, in a continuous improvement process that is part of the long term model.

In this context of innovation management and change management, Hatchuel (2000) has underlined the importance of ‘reciprocal prescription’ activities between actors in the conduct of design activities. According to Hatchuel, in such ‘specifier markets’, where product qualification is difficult, the intermediaries the markets constitute play a crucial role. Prescriptions that can in particular be ‘technical’ and ‘judgmental’ based on precise knowledge would constitute a condition for the functioning of the collective action that constitutes market exchange. These ideas have exerted an influence on academic marketing research, some of whose currents are now aiming to organize such prescription systems (Stenger, 2011).

A collaborative change management process could lead to a solution that satisfies all stakeholders at an acceptable level. To this end, this article shows how these actors and decision-makers must have multidisciplinary skills and resources, which make it possible to impose a sharing of value rather than a monopoly, implying that the partners involved can preserve their margin. Then, the question of capturing additional value will arise when the system is shown to be viable. In the case of spent grain, new markets, such as that of ‘*superfood*’ could be explored because it would maximize the margin of finished products, qualified with high energy or nutritional value. This step will require ensuring a secure and standardized supply. It will be necessary to scrupulously study the technological solutions of stabilization and transformation of spent grain to ensure their nutritional and energetic quality.

This is why the early stage of involvement of a new actor is major. This actor could be called the ‘degrainer’ and would have the major mission within the value chain to collect, stabilize, transform and redistribute the spent grain. Part of his or her work, in collaboration with the other actors, would consist of negotiating the new frontiers of concepts. Through these concepts, the services they negotiate, the business opportunities they are trying to capture or protect, and the new markets they constitute are at stake. The promotions, interpretations and definitions of new regulatory frameworks and associated standards will have to be rethought. In new economic sociology, Callon *et al.* (2000) conceive of the product as a ‘variable’ resulting from the ‘struggles and negotiations’ that the actors engage in during its qualification process. Even more so in the case of the revaluation of a coproduct from the food industry, a consensus on its characteristics can be difficult to reach. The finished products should meet lists of controversial global quality criteria due to assessments and judgments that vary from one actor to another, likewise for the values to be achieved for each quality criterion or even the objectivity and robustness of the procedures used to objectify them. Thus, all of the quality criteria for a product made from grains as a whole or in part could evolve as the product is transformed. Likewise, establishing the relative importance of each of the quality criteria for such a product would be an integral part of its collaborative qualification process.

Despite the nutritional value of spent grain, brewers, whose main mission is to make beer, very rarely have the resources (time, money, manpower) to deal with the grain problem. On the other hand, they willingly cede their deposits free of charge because, on the one hand, the subsequent user addresses the logistical problem of the spent grain or even saves them the cost of collecting and then discharging it. It is therefore a win–win partnership, albeit more often than not informal. Because of its great microbiological alterability, due in particular to its high water content and the elements of nutritional interest that it contains, the spent grain must be stabilized in a very short time (cooling, drying, separation, grinding, etc.) to limit or stop the fermentation of the material.

In terms of flow control, this processing step induces a logistical difficulty for reuse or subsequent processing because the volumes of spent grain arrive in batches at the end of each brew, unlike waste produced by chains processed online. To consider it as a useful material, therefore, large quantities of spent grain must be stabilized with each batch. For example, the combination of conventional unit operations of stabilization and then grinding would make it possible to produce flour of good nutritional quality, which would meet a need expressed by certain brewers, especially small and urban brewers. In addition, the incorporation of such flour

in (new) finished products would be part of a food offering that meets consumer needs and expectations in terms of sustainable positioning (upcycling of biowaste), virtuousness (supply local), health (nutritional aspect) and naturalness (minimally processed raw material)³. More specifically, with regard to the environmental impact, the factors involved include the reduction of waste at the source and the fight against food waste; the social factors include the local manufacture of products; the economic factors include the creation of added value for local players in a local circuit and the reduction in collection costs for (micro) brewers.

Because most microbreweries, craft breweries and small breweries do not produce enough spent grain to be reused on their own, cooperative solutions⁴ have already been studied. The development of cooperation between microbreweries has shown conclusive and innovative results based on a collaborative work base with urban agricultural cooperatives of similar volume and size that use the spent grain as compost. The actors involved became familiar with this use of spent grain, and companies were found to buy this compost. The very positive final report assessed business practices and models, logistics, costs, storage, packaging and partnership options. Such a study to revalue spent grain must address many aspects to ensure the success of the industrial technology and management initiative.

The logistical aspect of collecting and distributing spent grain is a major factor among those to be dealt with. Currently, start-ups intending to produce spent grain flour are looking for one or more subcontractors to organize collection, transport, and logistics in the most sustainable conditions possible. For some, this involves the use of electric vehicles or the use of soft mobility. The model of a Spanish company providing precisely this type of service, for large volumes, in a given geographical area, but for reuse in animal nutrition, can nevertheless be duplicated or adapted. This company offers support to the brewing industries of different types by managing the coproducts resulting from their industrial processes and improving their properties with the aim of increasing both the life cycle and the added value. They ensure the collection of spent grain with dedicated vehicles on a daily basis or just after the end of the brew to avoid paralyzing the plant. Distribution is programmed individually with each customer, in particular for feeding dairy cows. This distribution can also be daily. A pioneer⁵ in the collection of coproducts from the brewing industry, this company has contributed for 80 years to the responsible and sustainable management of spent brewer's grain.

In the case of animal nutrition, to ensure the inventory and storage of the spent grains, the installation of large-capacity silos (800 to 1,000 tons of spent grain, investment of 80,000 to 100,000 dollars) allows a refill approximately every two weeks. Previously, the grain was stored in 20-ton bins, which the users of the spent grain (farmers) overturned and then shoveled manually into a truck. Today, a silo valve opens, and the grain is automatically poured into the truck. For animal nutrition, this installation makes it possible to limit the excessively high costs of more frequent transport. For example, in the US⁶, some breweries estimate that they have to pay between 60,000 and 70,000 dollars per year for the transport and disposal (dumping) of spent grain. The silo solution facilitates collaborative work between collectors and users of spent grain. However, a simple transposition for human nutrition would be insufficient because of the rapid degradation of the raw material. The organization of the collection of spent grains is the first obstacle to the viability of improvement initiatives in human nutrition. To ensure a tight flow at the end of each brew, the different players involved will have to share production information, such as volumes and brewing frequencies. One could think of the utility, for purely managerial uses, of synchronized applications,⁷ such as those that put traders in touch with perishable unsold products and users ready to buy baskets of unknown composition at discounted prices. The value of this type of solution could first be demonstrated at the local level and then supported in other areas to develop similar initiatives with a view to making a greater impact.

³ <https://maltivor.com/>.

⁴ For example: <http://www.nogashi.fr/>; <https://boomerang-coop.com/>.

⁵ <http://fr.lpernia.com/services>.

⁶ At Weyerbacher Brewing <https://weyerbacher.com/>.

⁷ For example: <https://toogoodtogo.fr/fr/>; <https://www.wearephenix.com/>.

6. Conclusions

This article focused on the operationalization of the circular economy by seeking to highlight the implications of its implementation in the food industry. Examining the case of spent grain, this work took into account the points of view of different actors involved in the value chain and identified the brakes that should be lifted and the levers that should be mobilized for valuation in human nutrition. The extent to which such work around the revalorization of biowaste from the food industry can mobilize multiple and interrelated disciplinary fields was also demonstrated.

Developing an operational management of biowaste involves defining the technical, organizational and financial means adapted to a given context, the deployment of technical means of communication and cooperation of the different stakeholders, and the quality control of products from by-products. In particular, a specific collection allows the resource to be recovered under conditions that then allow it to be used, for example, in human nutrition, locally or not, in urban or peri-urban areas. From an economic point of view, the benefits associated with a *more intensive* recovery of waste bioproducts such as brewing dregs reduce costs as well as farm expenses. Pooled collection reduces individual costs through economies of scale. From an environmental point of view, more ambitious studies are needed to show how the reuse of nutrients makes it possible to reduce greenhouse gas emissions linked to the production of food. It also makes it possible to greatly limit the pollution of aquatic environments thanks to the reduction of nutrients in products rejected by producers, logisticians, and further users of products.

However, today, the installation and optimization of suitable equipment and processes constitutes a brake because specific skills are required to limit the use of energy flows (important in the context of the stabilization of a raw material that is produced at 80% moisture, leading to its rapid degradation that is not compatible with human consumption). Furthermore, current brewing tanks primarily require manual recovery of the spent grain. This operation requires either human labor or an investment. Several professionals are able to support communities to meet these challenges. This type of installation is an opportunity to educate users who often readily adopt the new system when they understand the stakes. Cooperation and the emergence of sectors and networks of actors will make it possible to remove these obstacles and better use biowaste.

Finally, the question of the real contribution of the circular economy to the reduction of impacts on ecosystems and species has to be addressed. Although product and service systems often aim at triple performance, environmental gains are often modest. In the case of spent grain, convergence can be found, but it encounters technical, sociocultural, legal or organizational obstacles. Not only is a great deal of work necessary to study the best parameters for the success of projects to revalue brewer's grain in human nutrition, but specific research related to sustainable development should be multidisciplinary.

Supplementary material

Supplementary material can be found online at <https://doi.org/10.22434/IFAMR2021.0154>.

Table S1. Summary of the interviews carried out for this study

Table S2. Value proposition of a circular valorization of brewer's spent grain.

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