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6 Beyond animal feed?

The valorisation of brewers' spent grain

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6.1 Introduction

The beer brewing industry has long been considered somewhat bio-circular since the major part of its organic side-stream, spent grain, returns to the biological system in the form of animal feed. In many places, spent grain has historically been given away free to farmers as livestock feed, especially for cattle. In terms of environmental sustainability, this can be a good management choice for the bio-economy, placing it between 'recycle' and 'reuse' in the waste pyramid (see Chapter 3). However, the fast deterioration of untreated spent grain requires the presence of local farmers as well as good transport infrastructure. Yet, according to Statistics Norway and Statistics Denmark since the 1980s, the number of farms has declined by 60% in Norway and Denmark, making the disposal of spent grain potentially more expensive and complicated. In addition, giving spent grain to farmers brings little or no revenues to breweries and prevents further valorisation of this resource. Globally, brewers produce about 38.6 million tons of spent grain a year (Lynch, Steffen & Arendt, 2016; Mussatto, 2014); so a change in spent grain management could therefore have significant environmental and economic impacts.

The large quantities of spent grain, along with an increasing interest in organic waste valorisation and circular bioeconomy, have spurred interest in developing new valorisation pathways as an alternative to the traditional use of spent grain as animal feed. Spent grain has a high protein content and other nutritional assets, and research projects have shown that it can be used as a feedstock in various industries, including livestock feed, food and nutrition, chemicals, pharmaceuticals and biofuels (Buffington, 2014; Mussatto, 2014; Thomas & Rahman, 2006). Yet, despite this technical potential, scholars have identified few examples of advanced uses of spent grain on an industrial scale (Aliyu & Bala, 2011; Mussatto, 2014), suggesting low levels of the deployment of research results.

Bugge, Hansen and Klitkou (2016) and Chapter 2 in this book identify different visions and perspectives on the bioeconomy: the biotechnology vision, the bio-resource vision and the bio-ecology vision. In this context, the bio-technology and bio-resource perspectives dominate the scientific literature on spent grain, which has a strong focus on biochemical and technological aspects, as is evident from the reviews (Aliyu & Bala, 2011; Mussatto, 2014; Thomas & Rahman, 2006). Socio-economic issues, such as value creation, competitive advantage, and consumer acceptance, have received less scholarly attention. And while the literature on technical options is rich and consistent, the few studies of the profitability of spent grain as an industrial feedstock report divergent results, ranging from optimistic (Mussatto, Moncada, Roberto & Cardona, 2013) to very pessimistic (Buffington, 2014).

In view of this, this chapter starts from the premise that company decisions on how to use and manage organic residues not only reflect technical possibilities but are also influenced by socio-economic, supply chain and regulatory factors. These include company-specific and industry-wide sustainability policies and initiatives, which can form part of companies' corporate social responsibility (CSR) efforts. In the brewing industry, important sustainability areas, apart from organic residues, are water consumption, waste water management, energy use and the resulting CO_2 emissions, sustainable packaging (Olajire, 2012), and responsible drinking. Integrating these sustainability areas into the core of a business can potentially increase value creation (Bocken, Short, Rana & Evans, 2013; Short, Bocken, Barlow & Chertow, 2014). In this regard, Porter (1985) argues that companies can obtain competitive advantage by pursuing a product differentiating strategy, where CSR can be a means of product differentiation (McWilliams & Siegel, 2011), through branding, for example (Roberts & Dowling, 2002), thus creating a non-imitational resource for the company (Reinhardt, 1998). In this context, Clark, Feiner and Viehs (2015) provide evidence of a positive link between CSR and a company's competitive advantage.

Against this background, this chapter aims to deepen the understanding of circularity in the brewing industry regarding organic waste. The specific aim is to investigate current management practices and options for valorisation of spent grain in brewing value chains in Denmark and Norway.

6.2 Value creation and sustainable competitive advantage

The exploration of alternative uses of spent grain encompasses potential economic gains, most obvious when a brewery incurs costs related to waste disposal but also when spent grain is given away for free. There are potential economic gains to be secured when creating a new value chain for spent grain. Yet these gains must be assessed in a cost-benefit setting. Benefits could also be related to CSR measures. How CSR can contribute to sustainable competitive advantage (McWilliams & Siegel, 2011) is elaborated on in Chapter 3.

Various industries use the principles of industrial ecology to convert waste to positive value assets, yet the literature lacks clear links to profitability and increased competitiveness (Short et al., 2014). Arguably, industrial ecology and, more narrowly, industrial symbiosis can be a foundation for business model innovation and it is important to look beyond conventional resource productivity and process innovation and find new ways of creating value (ibid.). Business models have been outlined in various ways. Whether it is the concept of marketing myopia (Levitt, 1960), value chains (Porter, 1985) or blue ocean strategy (Kim & Mauborgne, 2005), a business model essentially explains 'how a firm does business' (Short et al., 2014). Richardson (2008) sums up three aspects of business models: *value proposition, value creation and delivery, and value capture.* Business model innovation can take place in each of the three aspects, whether it depends on the product or service offered, and to whom it is offered, through which activities the value is created, or how the company handles costs and revenue (ibid.). Innovation in business models can spur sustainability (Short et al., 2014). Bocken et al. (2013) identify nine business model archetypes aiming to improve sustainability and one of them is *creating value from waste.* The strategy here is to eliminate waste and turn waste streams into inputs to other value-creating processes and production (Short et al., 2014).

Yet studies of the brewing industry emphasise the lack of change in the spent grain business model, i.e. the use of the residue as animal feed. There are many technical options for spent grain valorisation other than feed, as elaborated below, but brewers do not appear to have experimented with or implemented them (Aliyu & Bala, 2011) as a way of creating or capturing value. Even the Sierra Nevada Brewery in California, highly acclaimed for its sustainability measures, provides all its spent grain to farmers (Sierra Nevada Brewery, 2015).

Research and development (R&D) activities are playing an increasingly important role in companies' CSR policies (Baumgartner & Ebner, 2010). R&D is often integrated into the innovation and technology aspects of the economic dimension of sustainability, reducing the environmental impact of new products and business activities (ibid.). Engaging in R&D is particularly beneficial for companies that are among the first to adopt a new product, also known as 'first movers' (Robinson, Fornell & Sullivan, 1992; Srivastava & Lee, 2005). In light of this, it is interesting that the brewing industry does not have a tradition of making strong investments in R&D (Bamforth, 2000).

In view of these considerations, this chapter addresses the following research questions: What technical options exist for adding value to spent grain? What are the current status, opportunities and barriers for converting spent grain from low- or zero-value livestock feed into assets with a higher value? In this context, what R&D activities do Nordic brewers undertake regarding the management of spent grain and related areas and what motivates or hinders such activities?

6.3 Methods

This chapter is based on a case study of Nordic breweries and their handling of spent grain. The research follows a multiple case-study design (Bryman, 2015; Pettigrew & Whipp, 1991). Thirty-two breweries were selected through purposive sampling (Bryman, 2015). Seventeen were selected from Denmark from a database of 107 breweries (Ratebeer, 2017), and fifteen from Norway based on a list provided to the authors by the Norwegian Brewers' Association. The sample has breweries in a range of sizes, with a predominance of those producing up to 500,000 hectolitres of beer per year. Table 6.1 gives the key characteristics of the breweries that were interviewed for this study. We henceforth refer to the breweries by number rather than name to ensure the confidentiality of the information obtained in the interviews.

Eighteen breweries were interviewed through short telephone interviews, and an additional, in-depth interview lasting 90 to 120 minutes was undertaken with fourteen breweries following a semi-structured interview design (Bryman, 2015). The guide for the in-depth interviews was informed by a value chain approach and addressed topics such as firm characteristics, CSR strategies, spent grain value chain (structure, actors, coordination and technology), spent grain economics, alternative uses of spent grain, R&D projects, and policies and institutions. See Gereffi and Fernandez-Stark (2016) and the section on governance for waste valorisation in Chapter 3. We also reviewed academic publications and grey literature such as industry and company reports.

The interview data was analysed in two rounds. After structuring the data using the qualitative data analysis software Atlas (Atlas.ti, ver. 7.5.16), using an inductive approach, we derived five categories or factors of spent grain management from the interview data: economy, product, CSR, production and regulation. For each factor, we identified and described a number of variables, based on a review of the literature and the interview data. Table 6.2 lists these factors and variables.

Three *aspects* of spent grain management were likewise identified based on the nature of the interview statements: activities, opportunities and barriers (section 6.6), i.e. whether a statement related to an activity currently undertaken by the brewery, a future opportunity for alternative use or a barrier to realising such opportunities. The interviews were then screened again for relevant statements regarding spent grain factors and aspects. This analysis involved the quantification of the statements given in the interviews on the factors and aspects, as well as qualitative analyses. The results are presented in sections 6.5 and 6.6.

Table 6.1 Characteristics of the breweries interviewed in the case study

Brewery number	*Size (HL/Y)*	*No. of employees*[2]	*Gross revenue (€1,000)*[3]	*Year founded*	*Country*	*Interview type*[1]	*Position of interviewee(s)*	*Date of interview (month/year)*
1	116,900,000	42,062	8,422,249	1849	DK	F	Group CSR Manager	01/2015, 02/2016
2	9,700,000	2,350	852,848	1989	DK	P, F	Sourcing and Brewery Managers	01/2017, 02/2017
3	35,000	22	5,783	1902	DK	P, F	Brewmaster	12/2017, 02/ 2017
4	220,000	100	25,173	1999	DK	F	Technical and Plant Managers	03/2017
5	10,000	13	934	2012	DK	P, F	Brewmaster	11/2016, 01/2017
6	20,000	18	3,904	1998	DK	F	Brewmaster	03/2017
7	5,000	8	832	1897	DK	P	CEO	12/2016
8	800	3	93	2011	DK	P, F	Plant Manager	12/2016, 01/2017
9	15,000	7	N/A	2016	DK	P, F	Brewmaster	01/2017, 03/2017
10	740	2	N/A	2016	DK	P	Brewmaster and Owner	11/2016
11	1,500	3	N/A	2008	DK	P	Brewmaster and Owner	11/2016
12	30	3	11	1996	DK	P	Brewmaster	11/2016
13	2,000	12	348	2007	DK	P	NA	11/2016
14	500	1	87	2016	DK	P	Brewmaster and Owner	12/2016
15	3,000	7	291	2011	DK	P	Owner	12/2016
16	700	2	N/A	2013	DK	P	Brewmaster and Owner	01/2017
17	4,000	5	612	2003	DK	P	NA	12/2016
18[4]	1,410,000	1,133	533,548	1918	NO	F	Head of Development	06/2016
19	240,000	105	32,826	1904	NO	F	Brand and Product Responsible	02/2017
20	2,500	1	156	2011	NO	F	CEO and Owner	01/2017
21	20,000	38	6,366	2002	NO	F	Managing Director	03/2017
22	10,000	15	2,563	2009	NO	F	CEO	01/2017
23	3,000	17	842	2012	NO	P	CEO	02/2017
24	4,000	16	2,038	1989	NO	P	CEO	01/2017
25	3,000	7	731	2006	NO	P	CEO	01/2017

continued

Table 6.1 Continued

Brewery number	*Size (HL/Y)*	*No. of employees*[2]	*Gross revenue (€1,000)*[3]	*Year founded*	*Country*	*Interview type*[1]	*Position of interviewee(s)*	*Date of interview (month/year)*
26	5,000	8	1,653	2011	NO	P	CEO	02/2017
27	7,500	30	7,187	2009	NO	P	CTO	02/2017
28	9,000	24	2,080	2013	NO	P	Brewmaster	01/2017
29[5]	20,000	415	N/A	1918	NO	P	Marketing and Info. manager	02/2017
30	15,000	32	4,409	2003	NO	P	CEO	01/2017
31	135,000	56	22,748	2001	NO	P	CEO	02/2017
32	225,000	159	26,327	1995	NO	P, F	CEO	01/2017

Notes

1 F = Face to face, P = Phone.

2 Full-time equivalents (FTE) in 2016. Source: Own interviews.

3 The data source for breweries 1–4 and 18–22 is annual company reports, for breweries 5–17, www.datacvr.virk.dk, and for 23–32, www.proff.no.

4 This brewery is a subsidiary of brewery 1.

5 This brewery is owned by brewery 18.

Table 6.2 Factors and variables of spent grain management

Factor	*Variable*	*Description*
Economy	Direct costs	Costs that can be traced to specific cost objects such as a waste treatment fee or direct materials. Direct costs tend to be variable costs.
	Indirect costs	Costs that cannot be traced to specific cost objects. Indirect costs tend to be fixed costs or periodic costs (AccountingTools, 2017).
	Revenue	Income from the use and/or sale of spent grain.
Product		Quality and safety aspects of spent grain management that influence the quality of the main product (beer).
CSR	Water	Water use and water efficiency in the brewing process, including water content of the spent grain (Olajire, 2012).
	Climate and energy	Focuses on energy use, energy efficiency and energy conservation (Sturm et al., 2013). Includes activities to enhance biogas production.
	Waste	Activities related to the recycling, recovery or reuse of residues from brewing.
	Sustainable sourcing	Integrating sustainability into decisions regarding the production, distribution and purchasing of raw materials and products (Schneider & Wallenburg, 2012).
	Social issues	Strengthening the relationship with the local community including local farmers.
Production	Technical equipment and infrastructure	Quality or life endurance of technologies and equipment needed for brewing, storage or drying/enhancing of spent grain.
	Logistics	Logistical issues regarding the handling of spent grain. Transport and geographical distance are the main aspects.
	Size	Size and production capacity of the brewery, which can affect spent grain management.
Regulation	Regulation and policy	Influence of policy/regulations from regional, national and European authorities, including rules for subsidies and investments.
	Certification	Influence regarding standards for safety, quality or environmental compliance certification.

6.4 Technical options for spent grain use

Organic waste is defined here as 'biodegradable waste from gardens and parks, food and kitchen waste from households, restaurants, caterers, hotels and retail premises and similar waste from food processing' (Jürgensen & Confalonieri, 2016, p. 3). However, brewers' spent grain is not a waste product but the main side-stream from the beer brewing process and represents approximately 85% of all organic by-products from brewing. A large volume of spent grain is generated by the brewing process, around 20 kg per hectolitre of beer produced (Aliyu & Bala, 2011; Mussatto, Dragone & Roberto, 2006), and it is available all year round and at a low cost (Buffington, 2014).

In the wider context of sustainable production, these properties, together with its biophysical and nutritional attributes, have stimulated interest in adding value to spent grain, and numerous laboratory experiments have been performed with this objective in mind. These studies have been recently reviewed (Aliyu & Bala, 2011; Mussatto, 2014; Thomas & Rahman, 2006), revealing a great diversity in potential processes and products. Figure 6.1 shows the technical processes through which spent grain can be transformed into different product types (marked in bold), i.e. human food, animal feed,

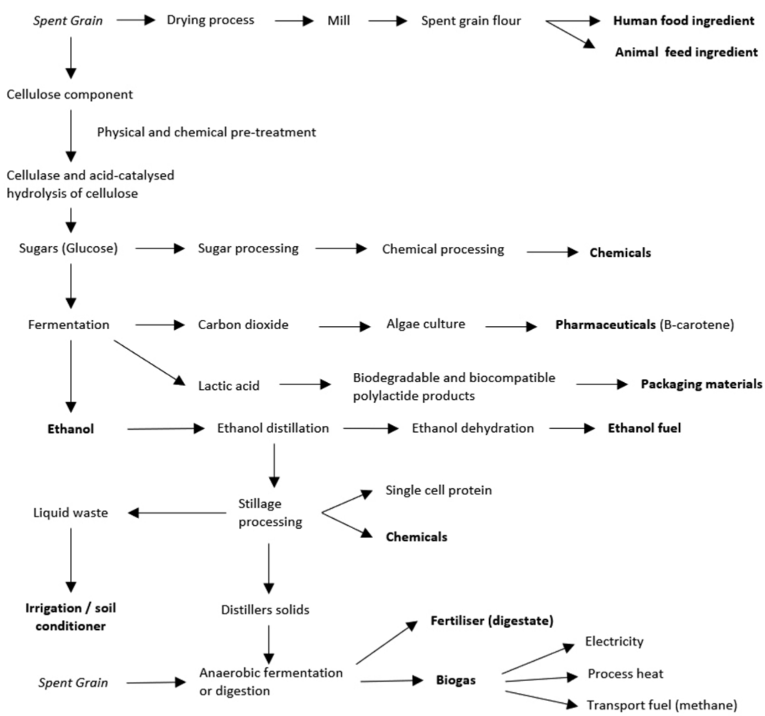

Figure 6.1 Technical processes and products based on spent grain.

Source: Adapted from Buffington (2014) and van Wyk (2001) chemicals, pharmaceuticals, packaging materials and energy resources (biogas, ethanol), along with the by-products (e.g. fertiliser) of these processes. Below we briefly discuss alternative valorisation options, drawing on the waste pyramid presented in Chapter 3: disposal, energy recovery, recycling, reuse and waste prevention. We do not assess whether one option is more sustainable than another, as this would require detailed life cycle analyses and also depend on local-specific factors.

Disposal. A key issue in handling spent grain is its high moisture levels. Spent grain consists of 70–80% water (Lynch et al., 2016; Thomas & Rahman, 2006), meaning that transporting spent grain is costly per kg of dry matter. Second, the rich polysaccharide and protein contents of spent grain make it susceptible to fast deterioration and spoilage (Thomas & Rahman, 2006), with associated health and smell hazards. Hence disposing of spent grain as a waste requires constant effort and can be expensive for the brewery, so this option is the least preferred.

Energy recovery. Spent grain can also be used in energy production, as it can show net calorific values of 18.64 MJ per kg dry mass and is thus interesting as raw material for combustion (Keller-Reinspach, 1989). Spent grain can also be used as a substrate for biogas or second generation-ethanol production, replacing natural gas and gasoline respectively (Mussatto, 2014).

Recycling. Using spent grain in animal feed has several positive benefits, including increasing milk production by cows and improving the meat quality of livestock (Thomas & Rahman, 2006). Spent grain can also be recycled as a soil conditioner. Combining spent grain with sludge or woodchips can improve soil fertility (ibid.).

Reuse as human food. Spent grain has high contents of fibre, protein and minerals, making it potentially attractive for human consumption. Experiments have improved properties in various food products including increased levels of protein and fibres in cookies (Öztürk, Özboy, Cavidoğlu & Köksel, 2002), bread and processed meat products (Thomas & Rahman, 2006). However, consumer acceptance and the quality of the final product need more attention (Mussatto, 2014).

Reuse in chemical processes. Applying spent grain in chemical processes has also been tested. Spent grain is rich in cellulose, polysaccharides and natural antioxidants, all compounds adding value to industrial applications. Furthermore, spent grain can be used in the production of paper-based products such as paper towels, business cards and coasters (Mussatto et al., 2006; Thomas & Rahman, 2006). The most promising use of spent grain in chemical processes is as an adsorbent for organic compounds from waste gas or dye from wastewater (Mussatto, 2014). Spent grain has also proved useful in biotechnical processes (ibid.).

Waste prevention. The amount of spent grain by-product generated per volume of beer produced depends on the brewing equipment; the type and quality of the vessel that separates the wort from the spent grain is especially significant when it comes to the efficient use of malt and water and hence for reducing the amount of spent grain. In general, a mash filter, employed by many larger breweries, generates relatively lower amounts of spent grain, compared to the less efficient and cheaper mash filtration method typically used by many small or craft breweries producing in smaller batches (Lynch et al., 2016).

6.5 Overview of current spent grain management

Figure 6.2 illustrates the current management of spent grain in Denmark and Norway, identified through the case study. The top part shows the brewing process and the origin of spent grain along with the (relatively few) instances where the spent grain is used as feed or fertiliser on the brewery's own farm. The bottom part shows the firms or units that process or use the spent grain after it has been collected at the brewery, alongside the different end uses of the spent grain. The dotted arrow shows a situation where a third party organises the transport and handling of the spent grain on behalf of the end users. While the figure gives the impression of diverse management regimes and uses of spent grain, the case study revealed that in the vast majority of cases the spent grain was delivered directly to local livestock farmers, as described below.

Nearly all brewers were connected to one or more farmers who used the spent grain as livestock feed, often for cattle and sometimes for pigs. The farmers valued the nutritional quality and protein content of spent grain. These agreements were often long term and were made with one or several farmers depending on the size of the brewery and the size of farmers' herds. The farmers usually collected the spent grain at the brewery. Some breweries, especially the large ones, received payments from the farmers, but most gave

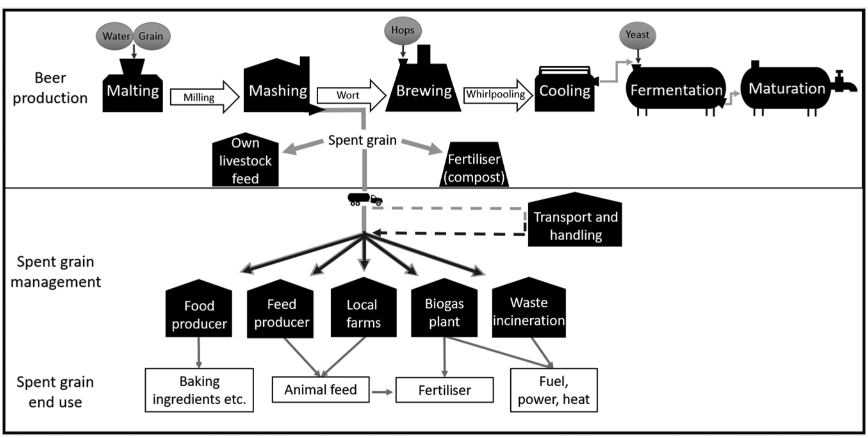

Figure 6.2 Overview of current management of spent grain.

Source: Authors' interpretation of interview statements made by brewers.

the grain away. In a few cases, an intermediary firm organised the collection of the spent grain on behalf of the farmers; in Denmark this was the case with brewery 2 among others, while the farmer buying grain from brewery 4 resold some of it to other farmers.

The price obtained for spent grain fluctuated depending on conditions in the feed market, including the price of substitute feed. The price also depended on the dry matter content, which partly depends on the brewing equipment. One large brewery (2) in Denmark received €16 (DKK 120) per ton from an intermediary, another €8 (DKK 60) per ton (3) from a farmer, while a third (4) received €134 (DKK 1,000) per ton from a local farmer acting as an intermediary. In Norway, one large brewery (32) could not obtain any payment from farmers for its spent grain, which was also the case for nearly all the small breweries (e.g. 5, 11 and 15). These significant price variations over time and space suggest a poorly functioning market for spent grain.

In a few cases, spent grain had other uses alongside or instead of simply being given to farmers. These were feed for the brewery's own livestock (5, 12), feed in high-quality wagyu beef production (30), compost on the brewery's own farm (8, 14 and 26), collection by a local biogas plant for a fee paid by the brewery (15), being sold or given occasionally to a local bakery (5, 22) and being disposed of as waste (21, 32). Two of these uses, as wagyu feed and as a baking ingredient, represent an improved use of spent grain compared to animal feed in terms of value added.

6.6 Why don't the breweries invest in alternative options?

This section analyses the interview data in more detail with a view to understanding what motivates current spent grain management, what brewers perceive as alternative management options and what hinders them in pursuing them. The last part of the section focuses on brewers' engagement in R&D projects in relation to these aspects.

Table 6.3 quantifies the interview statements of thirty-two brewers regarding the factors that influence aspects of spent grain management – i.e. current activities as well as opportunities for and barriers to alternative management options. Overall, economy (i.e. cost reduction) was clearly the dominant factor, with seventy-five statements, followed by production (47) and CSR (27). Brewers mentioned product (17) and regulation (8) less often. When considering activities only, economy is again the dominant factor, followed by production and CSR. The same pattern applies to opportunities. It is interesting to note that brewers considered production issues to be the main barrier to implementing spent grain management alternatives, followed by economy.

The interviews also produced qualitative data on the factors involved in spent grain management in terms of how they were seen to affect current activities, opportunities and barriers. The analysis below focuses on the dominant factors of economy, production and CSR.

Table 6.3 Number of interview statements by brewers in relation to factors and aspects of spent grain management

Aspect	*Activities*	*Opportunities*	*Barriers*	*Total*
Factor	*n* = 32	*n* = 28	*n* = 21	*n* = 32
Economy	39	22	14	75
Product	6	6	5	17
CSR	14	11	2	27
Production	16	16	15	47
Regulation	1	5	2	8
All	76	60	38	174

Note
The table shows the number of statements in interviews related to each factor (economy, product, CSR, production and regulation) and aspect (activity, opportunity and barrier). If more than one statement was made on the same combination of factor and aspect, then these were not counted, but when statements were made on several variables relating to a factor (e.g. direct costs and revenue in the case of economy) for a given aspect, then these statements were included in the count (therefore there are more than 32 statements on the combination of economy and activities). In total, 174 such statements were identified in 32 interviews. The sign 'n' denotes the number of breweries that gave a statement on the aspect in an interview.

6.6.1 Current activities

Economy was by far the most important factor in current spent grain management practices. Within this, cost savings were important for all breweries, while earning revenue was possible only for the large breweries (e.g. 1, 2, 3, 4 and 18). Risk management, in terms of avoiding a situation where spent grain exceeded storage capacity, generating expenses for waste disposal or even disrupting the brewing process, was also a key economic consideration. We also observed a close interplay between economy (cost savings) and production (mainly handling and storage of equipment, and location). CSR factors, in contrast, had only a minor influence on spent grain management among both large and small brewers. Where CSR was a motivation, it co-existed with or depended on other considerations such as profitability (1), compliance with public (20) or private (8) regulation, or simply convenience.

Spent grain is a potential health hazard; it quickly deteriorates, smells and fills the storage space of the breweries, and so the brewers perceived it mainly as an inconvenient by-product. None of the breweries owned technologies that allowed longer and safer on-site storage of the spent grain, such as cold storage or pressing/drying equipment. If it was not collected at regular intervals, it would force the brewery to halt production. Hence, many brewers emphasised the risks and the logistical and technical issues involved in handling spent grain. In this light, it is unsurprising that the dominant economic motivation for the current management of spent grain was reducing the costs of storage, transportation and disposal. Many brewers emphasised both indirect cost savings in terms of reduced labour time and 'hassle', as well as reduced expenditure on storage facilities, transportation and waste disposal fees (e.g. 5, 11 and 15). A case in point was brewery 1, whose strategy was to sell the spent grain at the 'highest price and with the least trouble'.

The waste disposal costs avoided due to the practice of farmers collecting the spent grain at the brewery gate are significant. In Denmark, one company specialising in the collection and treatment of food waste for subsequent use in biogas production was charging from €44 to €59 per ton plus transport costs, depending on the stability and volume of the waste, although large and stable volumes could attract a lower price (personal communication with company). In Norway, one brewery (32) paid around €101 per ton to dispose of its spent grain.

In this context, it is noteworthy that many brewers underlined the importance of having long-term agreements with reliable buyers or takers of the spent grain as a way to manage this production risk. Some brewers (e.g. 6, 32) found it difficult to get farmers to collect the spent grain year-round.

Production variables, and in particular logistical issues related to the geographical location of the brewery, also influenced spent grain management. In Norway, several small breweries were located far away from cattle farms, and the spent grain was therefore not used as feed. One brewery in northern Norway (32) had experienced reduced demand from farmers in recent years, especially during the summer, because of changes in feeding practices and fewer farm units. This meant that some of the spent grain was disposed of as waste, incurring the brewery costs in the order of €15,195 (NOK 150,000) per year. On the island of Svalbard, restrictions on waste disposal forced the brewery to ship the spent grain to the mainland, where it was disposed of as waste (21). As a solution, the brewery engaged in energy production on Svalbard replaced coal with a mixture of spent grain and demolition wood chips. Hence distance, combined with the volume of by-product, also determined whether brewers could sell the spent grain to livestock feed producers.

CSR motivated current spent grain management for some small breweries. For example, one brewery making certified biodynamic beer composted the spent grain and applied it to its own barley field to comply with the Demeter standard (8). Combatting climate change is a central part of the CSR brewery policy (1), and the company carries out CO_2 accounting across all its plants; however, spent grain management does not feature strongly in its CSR policy.

6.6.2 Opportunities

'Opportunities' refers to alternative ways of handling spent grain, which the brewers showed an interest in during interviews; some had concrete plans to adopt these in the future. Several alternatives to the current usage were mentioned. Many discussed the possibility of selling or using spent grain as a biogas substrate. Other alternatives were inputs on their own farms for composting or as animal feed, or selling to feed producers. Some brewers made general statements such as that they were 'interested in alternative ways of using the spent grain' (23, 24 and 25) without specifying the kind of alternative, suggesting limited knowledge of or interest in alternative uses.

Economy and production, followed by CSR, were the factors mentioned most often that could induce a switch in spent grain usage away from animal feed and disposal. Regarding economy, many mentioned the prospect of earning more revenue from the side-stream, often combined with technical and logistical measures. New equipment was sometimes mentioned (e.g. 32) as a key factor in changing the use of spent grain, especially equipment for dewatering the spent grain to increase its storability and reduce transport costs. Some emphasised the high quality of spent grain as an animal feed and the potential economic benefits of its nutritional value. One brewer asserted that spent grain 'contains a lot of vitamins and minerals [of benefit to humans], but these are currently not properly utilised' (18), and another that spent grain 'is quite sought after because it is good for the digestive system of animals' and this can improve the quality of meat for human consumption (19).

The most common incentives mentioned under CSR were the environmental benefits in terms of improved waste handling or recycling, sustainable sourcing and to a lesser extent climate mitigation. Sustainable sourcing was expressed in 'circularity' terms such as 'closed cycle' (10) and as an example of 'responsible thinking' (21). These incentives were often expressed as an aspect of other incentives such as improved product. One brewery believed that the reuse of spent grain in production would have simultaneous economic, environmental and product-quality benefits that could be exploited in marketing and consumer communication (22), as shown by the example of the Sierra Nevada brewery in the USA.

Finally, some brewers connected an alternative use of spent grain to certification, either regarding product and food safety, or as part of a broader environmental responsibility certification. In this regard, brewery (21) emphasised its comprehensive view on sustainability, which it planned to express and implement through Environment Lighthouse certification the following year.

6.6.3 Barriers

Barriers are the perceived obstacles to switching to an alternative use of spent grain. Economic and production factors were the barriers most often mentioned by brewers. In terms of *economics*, many expressed an unwillingness to invest time and effort in changing their management of spent grain due to the indirect costs involved in terms of staff time (e.g. 9, 10, 14 and 23). One brewery (10), for example, considered that implementing changes to install such a system was 'too difficult and too much work', especially in light of its lack of storage facilities and the limits imposed by regulations. Another brewer (14) was interested in selling the spent grain to bakeries, but time was the main constraint to developing this option, and like other alternative options it remained at the experimental level.

Brewers often mentioned such economic factors in combination with production variables, specifically an insufficiency of *equipment or storage space*, and several brewers (e.g. 18, 32) stated that they lacked the equipment to dry the spent grain and store it for longer periods. Moreover, EU and national regulations on fodder production require safe storage of spent grain, as emphasised by brewery 18. Yet it is noteworthy that many medium-sized and large breweries (6, 10, 22, 27, 28, 30 and 31) did not perceive production variables, including transport, to be a barrier to implementing new options, or as a negative aspect of current operations.

Securing the *investment finances* needed to upgrade or replace the equipment that would enable alternative uses of spent grain was also seen as a barrier. Brewery 2 noted that it had run trials to dry and burn the spent grain for energy production, but that it would need to invest in new equipment to do so on a large scale. Brewery 4 observed that its brewing equipment was old and therefore resource inefficient. In particular, the vessel that separates the wort from the spent grain is crucial for the efficient use of malt and water and hence for reducing the amount of spent grain per volume of beer produced. However, investment in such equipment had so far been outcompeted by more customer-focused investments, most recently a new bottling line.

Some respondents (7, 25) noted that the expected *low returns from investments* in alternative uses of spent grain made it difficult to access finance from within the firm, while others (e.g. 1) emphasised the importance of having a good business case, including for 'green' projects. Indeed, many mentioned the need for cost efficiencies in all parts of an operation and this was related to the strong competition and low-value nature of beer (2). In this regard, one brewery (32) observed that getting approval for a project with a payback time of more than two or three years depended on the size of the investment and how well it compared to competing projects. As mentioned above, brewery 4 had recently invested in new, expensive bottling or filling lines, requiring significant financial resources.

Firm size also influenced a firm's ability and willingness to invest. Several breweries (5, 7, 23, 24 and 28) observed that their small size reduced their ability to pursue alternative spent grain options, and brewery 24 noted 'we are too small, and the alternatives are too complicated and costly'.

Given the above considerations, the opportunities to implement greener products and techniques may well be greatest in situations where core brewing activities are undergoing significant changes, such as when production capacity is expanded (31) or the brewery is relocated to a new site (17). Regarding *CSR* as a factor for spent grain usage, one important regulatory barrier mentioned (by brewery 1) was the lack of a system whereby the brewery could receive carbon credits for the biogas produced 'off-site' by other companies from its spent grain. This limited the CSR benefits of selling spent grain to third-party biogas producers.

6.6.4 Involvement in research and development projects

Nine of the thirty-two breweries interviewed mentioned R&D projects, and thirty-nine statements relating to R&D were obtained (Table 6.4). Twenty-two statements on R&D concerned opportunities for engaging in future R&D projects, while only nine referred to current R&D activities, reflecting a generally low level of engagement in such projects. That said, the vast majority of brewers were continuously engaged in the development of new products, product variants and process optimisation without perceiving these efforts as R&D projects. Addressing sustainability issues was rarely the focus of these activities. In the words of brewer 19, ‘We don’t think about research because it is product based, so we say, “OK, here’s something we can do better”, and then we need to find a solution to make it better’.

Breweries with ongoing R&D projects were collaborating with research institutions, as well as private companies. Two Danish brewers (1, 2) were working with the Technical University of Denmark on spent grain innovations and sustainable packaging. One Norwegian brewery (30) was collaborating with the Norwegian University of Life Sciences and a food company on a project to develop cattle feed based on spent grain mixed with traditional feed ingredients and tailored to the production of high-value wagyu meat. There were also R&D collaborations in other areas of sustainable production. For example, brewer 2 was working with several firms and municipal institutions on energy efficiency and industrial symbiosis, while brewer 1 was working with the Carbon Trust to measure the carbon footprint of its value chain and develop a road map to meet its targets for reducing greenhouse gas emissions (The Carbon Trust, 2017). Lastly, some breweries were engaged in knowledge generation through meetings with other breweries or via the brewers’ association in their respective countries.

Table 6.4 Number of interview statements by brewers in relation to factors and aspects of engagement in R&D projects

Aspect	*Activities*	*Opportunities*	*Barriers*	*Total*
Factor	*n*=6	*n*=5	*n*=4	*n*=9
Economy	–	3	7	10
Product	3	3	–	6
CSR	6	12	–	18
Production	–	3	–	3
Regulation	–	1	1	2
All	9	22	8	39

Note
The table shows the number of statements in interviews related to each factor (economy, product, CSR, production and regulation) and aspect (activity, opportunity or barrier). The sign ‘n’ denotes the total number of breweries in the size class which made a statement on the aspect in an interview. The answers are from interviews with four large and five small breweries that included R&D aspects in their answers.

Opportunities for taking up new R&D projects were a common topic addressed in interviews, where CSR was the dominant factor (Table 6.4). One brewer (1) was interested in assessing the broader environmental impact of alternative uses of spent grain in relation to energy, land use and greenhouse gas emissions. Also from a sustainability perspective, two brewers were interested in research projects on energy efficiency and renewable energy (2, 5), while a long-term objective of brewer 5 was certification in LEED (Leadership in Energy and Environmental Design), a green building rating system (US Green Building Council, 2017). Other favoured topics were water savings, sustainable packaging and ways of reducing the company's overall environmental footprint. Brewery 22 emphasised that more information and learning possibilities were critical for transitioning to more sustainable production:

> This is not a matter of subsidising investments and upgrades. This is a matter of obtaining information on feasible ways of improving production processes, i.e. consumer information in the same sense as you get when you buy domestic appliances. In other parts of the primary sector, e.g. agriculture, it is common to have knowledge and counselling centres.

Brewery 9 likewise stressed the need for increased knowledge generation and sharing within the craft brewery side of the industry.

The perceived barriers to engaging in R&D projects were mainly economic (Table 6.4). One brewer (9) found that the labour costs of preparing funding proposals were a key obstacle, while another (19) anticipated that entering into R&D projects would involve significant operational costs in terms of professional and administrative staff time. There were also perceived regulatory barriers to involvement in R&D, such as compliance with the EU Best Available Techniques (BAT) regulation (Kawa & Luczyk, 2015; Kristiansen, Johansen, Mou & Johansson, 2011; Olajire, 2012). Hence, brewery 2 anticipated the risk that their R&D projects would be viewed as either too broad or not feasible to implement under BAT rules.

6.7 Conclusion

The management of spent grain observed in the case study categorises it as part of the bio-resource vision, while alternative uses would introduce the other two visions, bio-technology and bio-ecology, as well as opening a debate around system boundaries. For example, if a brewery used spent grain for biogas production to enhance their greenhouse gas performance, it might have negative consequences for the sustainability of the wider system, i.e. for farmers, food production and land use. Our study also showed that the Nordic brewing industry has not developed a clear vision of the bioeconomy in relation to its organic residues, let alone implemented major initiatives in this area, thus confirming the common view of the industry as 'traditional in approach' (Bamforth, 2000).

Several of the alternative uses of spent grain discussed in this chapter could potentially enhance value creation and capture and perhaps even provide brewers with a sustainable competitive advantage. First, brewers could obtain a higher price for the spent grain compared to the present situation, which will have a direct financial impact. Second, brewers could promote their alternative uses of the spent grain and thus increase their branding value. Yet there are also reputational risks involved in denying farmers access to a local feed resource by diverting spent grain to other uses, and brewers could get entangled in the food-feed-fuel debate by using spent grain for energy production. Notably, given the historical lack of innovation in this sector, implemented new uses of spent grain would take time to imitate, thus creating at least a temporary competitive advantage for the first movers.

The spent grain valorisation pathways identified by this and other studies are clearly downstream and involve other value chains, meaning their realisation must include other industry actors. Brewers need to acquire new market knowledge, especially about downstream complementary assets (Roy & Sarkar, 2016). This requires internal strategies for acquiring knowledge and depends on collaboration with non-brewers who possess the required knowledge and resources, including processors, technology suppliers, researchers and financiers. Brewers' current limited engagement in collaborative R&D projects appears to be a hindrance to pursuing such a strategy.

Deploying new pathways and business models for spent grain will have consequences not only for the actors in the brewery sector and downstream sectors directly engaged in spent grain utilisation, but also for wider society when spent grain finds new uses. The geographic context of the breweries influences the possible demand for valorisation of spent grain, such as the demand for use as feed. In order to understand which valorisation pathways are 'better', one must investigate several questions: In which sustainability dimension(s) is one pathway better than another? Who is the pathway better for? What business model innovations will the pathway rely on? What kinds of breweries would it be relevant for? A further topic for future research is the development of industrial symbiosis between breweries and other industry actors with the potential to valorise the spent grain and other resources such as excess heat, water, etc. A final important topic is the interaction with intermediaries through which brewers can access better knowledge about possible new applications, markets and technologies.

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