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## Overview of the Irish brewing and distilling sector: processing inputs supply and quality requirements

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# Overview of the Irish brewing and distilling sector: processing inputs supply and quality requirements

For any brewing and distilling establishment, the supply and quality of processing inputs is a major determinant in its production output. Accessibility and availability of brewing and distilling inputs drives productivity and quality of products. The Irish brewing and distilling sector have shown increased sales and production output, with a growth rate of 4 % between 2014 and 2019. The brewing industry in the republic of Ireland has seen a 22 % increase in the number of micro-breweries since 2014, and its total output now stands at 8.3 m hectolitres. The distilling industry witnessed an increase from four to thirty-eight in the number of distilleries between 2010 and 2020 with a local and global sales at 2.4 and 20 million nine litre cases, respectively. As a result of the continued growth of the Irish brewing and distilling sector, demand for different processing inputs has increased proportionately. For a sustainable production process, there is need for a steady supply of the right quantity and quality of the major inputs for brewing and distilling. Sustainable growth of the sector requires establishment of a strong base of processing inputs availability and their effective utilisation to minimise environmental impacts. This review, therefore, looks at the current state of the major processing inputs for brewing and distilling in Ireland, as well as their general characteristics and requirements.

Descriptors: brewing, distilling, Ireland, processing inputs, sustainability

## 1 Introduction

Processing inputs are key process inputs that have significant impact in a process output variable. They drive productivity and output and are highly significant in a product value chain. In brewing and distilling, these range from key raw materials like water, grains, yeast, and hop to energy and packaging inputs. The productivity and quality of beer and spirit products is facilitated by the nature and supply of these different inputs that goes into the manufacturing process. These processing inputs are critical to the overall performance of brewing and distilling unit operations, and will drive the output and quality of the resultant product(s) [1]. To achieve the best desired products in brewing and distilling especially with respect to quality of products, economy of the process, and minimal impact on the environment, it is important to make use of the best available inputs in the production process. Assessment of processing inputs assessment constitute real economic opportunities for improvements, and the specificity of brewing and distilling process requires some level of consistency in the development and acquisition of the different processing inputs. Therefore, it is

essential that a great deal of effort is made to ensure a careful selection and management of these inputs in order to achieve an uninterrupted production and enhanced performance in operations.

The brewing and distilling sector of the Irish drinks industry have recorded tremendous growth over the years with average growth rate of 4 % per annum [2, 3]. Beer and spirits in the Irish drink market have a market share of 39 % and 22 % respectively. Presently, Ireland is the 7<sup>th</sup> largest exporter of beer in Europe and the 8<sup>th</sup> largest producer of spirits in Europe producing an average of 800 million litres of beer and 190 million bottles of spirits annually [2, 3]. Growth in output of the sector has been consistent since 2014 (Fig. 1, see page 10) and this can be attributed to increase in popularity of the Irish brands of beer and spirits, and a proportionate rise in the total number of breweries and distilleries in the sector. The Irish brewing industry witnessed a tremendous growth in the micro brewing sector, growing from 15 microbreweries in 2012 to up to 75 microbreweries in 2018. While in the distilling industry, total number of distilleries in Ireland grew from 4 distilleries in 2010 to 38 distilleries in 2020. The growth of beer and spirits production in the republic of Ireland, despite it being positive, has taken a toll on processing inputs requirements and utilisation by the sector. For example, grain is a major input for the Irish brewing and distilling sector, and it is estimated that the sector is supported by approximately 300,000 tonnes of grains annually, of which 220,000 is barley malt [4, 5]. In addition, there has been a proportionate increase in the importation of significant quantities of grains annually to match the demands of the sector. Importation of cereals for brewing and distilling grew at a linear rate of 64,000 tonnes annually from 2000 to 2018, reaching 1.6 m tonnes in 2017 [4]. The distilling industry

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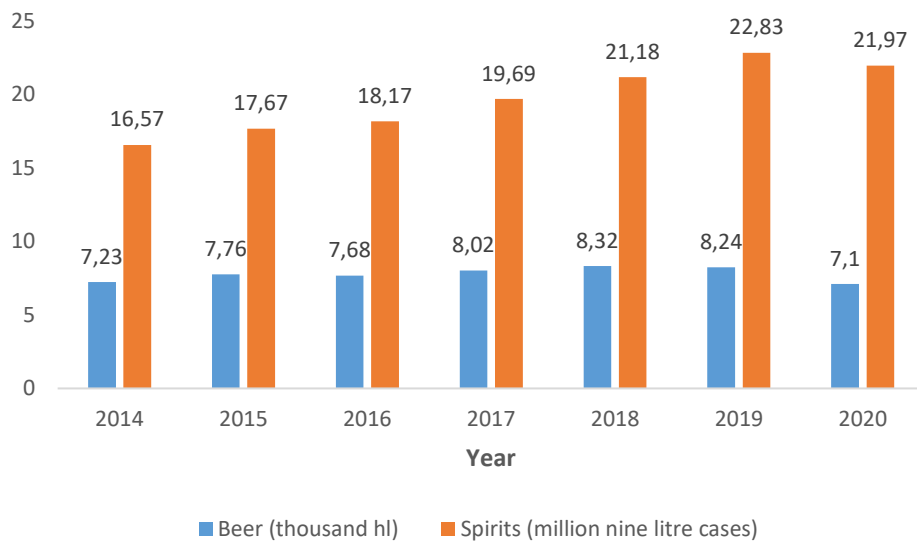


Fig. 1 Total beer and spirits output in Ireland (based on Drinks Ireland[2, 3])

in Ireland uses approximately 115,000 tonnes of imported maize each year [4]. In the case of malt, Ireland’s net export position which was about 40,000 tonnes annually during the early 2000s has dropped. At present, Ireland is now a net importer of malt as opposed to its net export position in the early 2000s.

As a result, one of the key issues facing the Irish brewing and distilling sector is the establishment of a strong base of producers providing inputs for the sector on a sustainable basis. For example, grain source and development are a key aspect of the drinks industry, and thus, there is the need for an organised approach to increase the output and range of the tillage sector to meet the growing demands of the brewing and distilling sector in Ireland. Many experts have argued that apart from a sustainable business environment, sustainable production is also needed to ensure a continued growth of the brewing and distilling sector in Ireland [4–7]. However, for this to be possible, there is a need to first understand the processing inputs requirements and utilisation of the sector. This review therefore focuses on processing inputs requirements and utilisation in the Irish brewing and distilling sector.

## 2 The Irish brewing and distilling sector

### 2.1 Economic performance of the sector

In the last decade, investments in the Irish brewing and distilling sector have witnessed substantial growth rates and this can be attributed to expansions and growth in the number of Irish whiskey distilleries and microbreweries establishments. The brewing and distilling sector (spirits, beer, and cider) in Ireland accounts for 75 % of the country’s total drinks exports in over 125 markets worldwide [7]. The alcoholic drinks exports in Ireland have created its own niche in the drink industry and with its high value and branded products, it is seldom affected by common changes in global commodity markets. Value of spirits exports in Ireland has also continued to increase, with the US and the UK as top export destinations. Export value for beer in Ireland was € 305 million in 2019 and € 254 million in 2020 while that of spirits was € 1.17

billion in 2019 and € 0.99 billion in 2020. Table 1 gives a breakdown of production share for the different beer types and spirit products produced in the republic of Ireland. From table 1, stout remains Ireland’s favourite beer type with a production share of 66.5 % in 2020, and vodka is Ireland’s most popular spirit category with a production share of 31.59 % in 2020 followed by whiskey and gin with values of 26.27 % and 14.05 %, respectively [2, 3]. Specifically, the Irish whiskey industry has witnessed a phenomenal growth in recent years and has been tagged as the world’s fastest-growing spirits category in the past decade. This is seen in its increased sales of under 5 million cases in 2010 to 12 million cases in 2020 with an annual growth rate of 9.1 % [3]. The current performance of the brewing and distilling sector in Ireland presents a huge

prospect for the supply chain and an opportunity to re-evaluate the processing inputs use and supply.

### 2.2 Impact of Brexit on Irish grain imports and alcohol exports

An enormous proportion of barley and wheat imports in the republic of Ireland come from the UK, while grains like maize most of the time travel via the UK prior to its delivery in Ireland. In the export of Irish beer and spirits, the UK is the major market for the export of Irish beer and ciders. According to data from the Central Statistics Office, 71 % of all beer and 85 % of all cider exported in the republic of Ireland in 2017 went to the UK [8, 9]. In addition to grain imports and drinks exports, an estimated 130 million glass bottles are imported from the UK to the republic of Ireland annu-

Table 1 Production share for beer and spirits products in Ireland

	Ratio (%) 2018	2019	2020
<b>Beer type</b>			
Stout	63.1	64.3	66.5
Lager	30.7	29.8	28.0
Ale	6.2	5.9	5.5
<b>Spirits products</b>			
Vodka	33.71	33.74	31.59
Irish whiskey	25.08	25.19	26.27
Gin	13.88	14.44	14.05
Rum	7.27	7.36	7.42
Brandy	5.10	4.99	4.79
Other liqueurs	4.84	4.85	5.16
Irish cream liqueur	4.09	3.81	5.03
US whiskey	3.14	2.99	3.09
Scotch whisky	2.21	1.91	2.09
Tequila	0.69	0.73	0.51

Based on Drinks Ireland [2, 3]

ally [8, 9]. Furthermore, the Irish drink sector activities across the republic of Ireland-UK border includes an annual movement of over 23,000 trucks of which at least 5,000 of these are alcohol-tanker movements [8, 9]. The EU Single Market has been instrumental to the ease of these trade and movements across republic of Ireland and the UK because of the free movement of goods and services, and a common set of standards, rules and specifications for goods and services. The EU Single Market has also helped to facilitate cross-border supply chains and trade between republic of Ireland and the UK, and between Northern Ireland and the rest of the EU. However, the withdrawal of the UK from the European Union (Brexit) has hugely impacted on this EU Single Market affecting both grain imports and drink exports from and to the UK, respectively. With a limited or a no-deal Brexit, the Irish drink industry is faced with inevitable changes in grain imports from the UK as well as the exports of its finished products to the UK. It has been reported that trade volumes between republic of Ireland and the UK have fallen significantly post-Brexit compared to same periods before Brexit, and this has been attributed majorly to changes in custom requirements following Brexit. In general, the Central Statistics Office [10], reported a fall of 65 % of imports from the UK in January 2021 compared to the previous year prior to Brexit. Also, comparing same periods for pre- and post-Brexit, exports from the republic of Ireland to the UK decreased by 20 % [10]. More specifically, the perceived implication of Brexit on grain imports within the republic of Ireland is a more stringent requirements in the imports (including tariffs, customs checks and up-front VAT payments), and this may consequently reduce grain availability for its drinks industry and increase demand for domestic grains. While this may not be good news for the Irish drink industry, it is an opportunity to boost productivity and output of the tillage sector to reduce the reliance on imported grains to some extent. More impacted by Brexit in the last one year is the export of Irish drinks to the UK. While the US remains the major export market for Irish whiskey, large proportions of Irish beer and cider are being exported to UK annually. The Irish Food Board reported that Irish alcohol exports to the UK in 2020 reduced by 12 % compared to 2019 [11]. But it is difficult to say how much Brexit played in this drop as there is also the implication of the closure of the on-trade globally because of COVID-19 pandemic. However, the Irish Food Board in their report noted that the value of the exports (alcohol) is 12 % higher than it was in 2016 before Brexit. While the dynamics and challenges of Brexit for the drink industry in the republic of Ireland continue to unfold, there is no doubt that it has impacted the drink sector. At present, it is difficult to measure or estimate how far Brexit has affected grain imports and alcohol exports in Ireland because of other factors and changes that has taken place in the last one year including COVID-19 pandemic, US tariffs and Brexit stockpiling. However, soon, the exact impact of Brexit on grain imports and alcohol exports might be easier to estimate, and these will no doubt

require changes or adjustments in production patterns and market segments for the industry.

### 3 Processing inputs for the brewing and distilling sector

#### 3.1 Barley

Barley, in its malted form is a basic raw material for brewing and distilling. It provides the primary source of fermentable sugars for yeast metabolism in beer and spirits production [12]. This makes malted barley to be of more significance in brewing and distilling than the whole barley grain. Barley malt utilisation for brewing and distilling can be divided into three groups based on the forms in which they are used. These include: (i) pure barley malt brewing, (ii) barley malt for adjunct brewing, (iii) distilling barley malt. Each of these uses of barley malt has distinct requirements. Pure malt brewing requires malts with high extract values, high enzymatic activity, and good modification characteristics [13]. For adjunct brewing where another source of fermentable substrate is utilised in the brewing process, barley malt with high starch digestibility, high diastatic activity, and appropriate level of malt extract is desirable. For distilling malt, the primary requirement is the ability to synthesise high levels of fermentable sugars to maximise spirit production [14]. Hence, distilling malt should have high enzyme activity.

##### 3.1.1 Barley in Ireland

In Ireland, barley is the highest cultivated tillage crop [15], providing valuable input for brewing and distilling in Ireland. The Irish brewing and distilling sector utilise an estimated 250,000 tonnes of barley annually [4] supplying only 40 % of the demands of the distilling industry. Irish distillers make use of about 65,000 – 70,000 tonnes of barley each year, and this number is expected to double in ten years [6]. As a result of the increase in number of breweries and distilleries, the import dependence of the sector has increased across the major grain inputs required for their

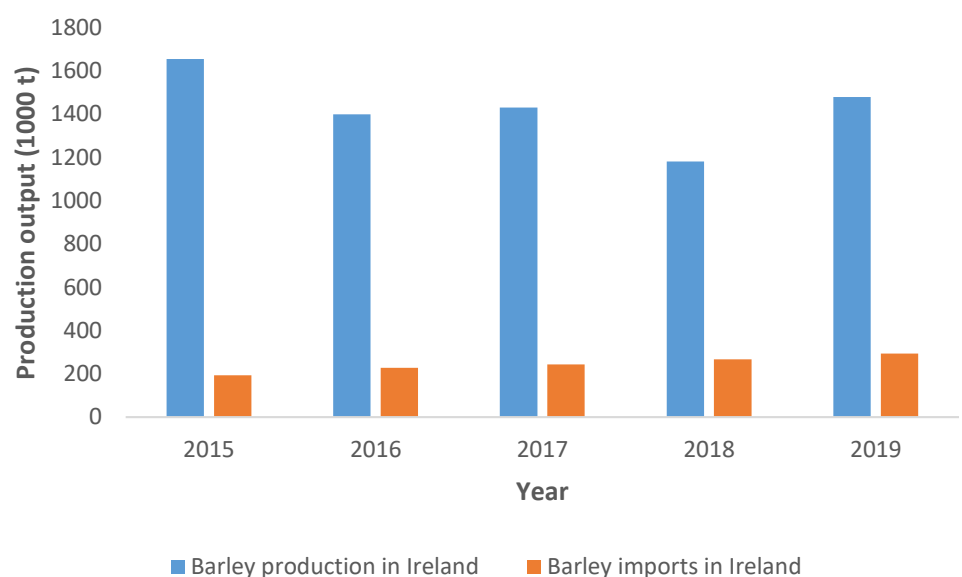


Fig. 2 Barley production and imports in Ireland (based on FAOSTAT[26])

activities – Ireland has an average annual barley production of 1.5 million tonnes which has not been very consistent over the years (Fig. 2). However, increase in beer barley imports has remained constant in the last five years (Fig. 2), and this period corresponds to the time the country began to witness growth in the total number of microbreweries and distilleries. This suggests that the rate of increase in Ireland's barley production is not enough to meet the growing demands of the brewing and distilling sector hence the increase in quantities of imported beer barley. This has reduced Ireland's self-sufficiency in locally produced cereals to 88 % [4]. With increase in market and export value for Irish beer and spirits, demand of barley for brewing and distilling continues to increase. The Irish drinks industry needs a strong base supply of barley and research could help address this by looking into ways barley growers can meet the specific requirements for malted barley or look at alternative grain resources for brewing and distilling.

A report by Teagasc [15] enumerated the typical traits of barley for brewing and distilling in Ireland. For brewing barley, these include: a good balance of grain starch and protein contents (protein: 8.8 – 10.8 %; sugar extracts: > 81 % dry matter; free amino nitrogen: > 210 mg/L), good potential for enzymatic protein and sugar degradation, high extract level, ability to produce small nitrogen compounds for the yeasts, plump kernels for synthesis of more starch, even kernel sizes for a more homogenous malting, and a strong husk to help improve the efficiency of the brewing process. In addition to all these, it is necessary for brewing malt to have a good level of cytolysis or cytolitic modification (disruption of the cell walls by cytolitic enzymes to make the starches more accessible and more fermentable), which is one of the aims of barley breeding programs. For distilling, the barley requirements are relatively different from that for brewing. Unlike brewing, distilling operations aim for very high extract levels with little interest in the flavours driven by malt. As a result, typical distilling barley should have a relatively low protein content (8.5 – 9.3 %) compared to the sugar levels with no glycosidic nitrile. Large and uniformly sized kernels are preferred for increased sugar production and a homogenous malting process respectively, and the production spirit yield should be greater than 410 litres of alcohol per tonne of malt [15].

### 3.1.2 Barley breeding programs in Ireland

Breeding programs in agriculture is one of the key drivers to boosting productivity and profitability of agricultural produce [16, 17]. Yield, productivity, disease resistance and other quality parameters of crops have been improved via targeted breeding programs [16, 17]. The need for Irish tillage farmers to grow barley grains that meet specific requirements of the brewing and distilling sector is paramount and requires knowledge of the distinct specifications from the sector. In Ireland, there are ongoing efforts to ensure that the tillage sector continues to deliver high quality grains for brewing and distilling. A great deal of research by different stakeholders across the tillage and drinks industry goes into making available recent and accurate data to growers to enable them exploit growing conditions and maximise output. Teagasc is making a great deal of effort in that regard via its breeding programmes aimed at delivering more brewing and distilling barley within specification and publication of the Annual Spring Barley Guide to bring awareness to tillage farmers on optimal barley growth and output [15–17].

There is also the joint malting barley development programme also by Teagasc which is aimed at development of barley with more brewing and distilling specification, trialling of winter barley to offer growers more cropping options for malting barley and increasing profitability through effective soil nutrient management plan [18]. The trials for winter barley varieties Pixel and Craft (which is already gaining interest in Ireland), examine the agronomic performance and malting quality of winter barley under Irish conditions. Another example of an initiative to boost barley production for brewing and distilling in Ireland is the malting barley variety committee which is made up of stakeholders across the tillage and drinks industry with a key objective of developing higher value varieties of barley suitable for malting.

In addition to these breeding programs, the Irish brewing and distilling sector more specifically is also making efforts for barley sustainability across the sector. Irish malt distillers pride themselves in the utilisation of Irish barley and have committed to reversing the loss of area planted under Irish spring barley and under tillage generally in its climate action goals [19]. There is also the Sustainable Green Spring Barley Scheme by Irish Distillers in collaboration with Irish Farmers Association. The scheme's objective is to support and encourage long-term viability of the spring barley sector in Ireland by rewarding farmers delivering environmental sustainability initiatives on their farms [19]. The scheme also targets to deliver sustainability requirements for spring barley, facilitate on-farm biodiversity and help farmers attain their sustainability initiatives.

## 3.2 Yeast

### 3.2.1 Brewing yeast

In brewing, the most significant change in the whole fermentation process and wort development into beer is brought about by the action and activities of yeast cells. Brewers select yeast to be used for brewing based on the specific character of each beer type (lager, ale, or stout) mostly using different strains for each type. For example, lager beer production uses a different strain from ale beer production, and there are differences between these strains [20]. The ideal key characteristics brewers look out for when selecting brewing yeast include: (i) ability of the yeast to synthesise alcohol and other desirable flavour compounds, (ii) ability of the yeast to reach the desired degree of fermentation (attenuation), (iii) ability to be consistent in its flavour profile production, (iv) ability for the yeast to complete the fermentation process within the set time, (v) ability to retain viability and genetic stability during fermentation and storage, and (vi) ability to ferment the sugars present in the wort and reproduce appropriately [20, 21].

### 3.2.2 Distilling yeast

Proper yeast selection just like in brewing is equally important in distilling. Before now, minimal attention was paid to the selection of distilling yeast. It was common to find most distillers using the same yeast strain as brewing yeast for whiskey fermentation. However, nowadays, special strains of yeast have been developed specifically for distilling. The distilling yeast strains are made to tolerate high alcohol contents and a broader range of substrates

than brewing yeast strains [20]. These strains of yeast for distilling possess a unique genetic make-up that allow them to utilise a broader range of substrates and they also have better fermentation tolerance ability [22]. The desirable qualities for distilling yeast strains include production of high yields of alcohol, high tolerance for pH, temperature, sugars and osmotic pressure, good flocculation properties, and good viability during storage and before pitching [22]. Another key characteristic of distilling yeast is the strain's fermentation time lag (the growth phases) and formation of the right form of metabolites in the product [23]. Target theoretical alcohol yield for distilling yeasts strains is 90 % [22], and unlike in brewing, the yeasts used in distilling are not recycled. This is because the high alcohol requirement for distilling yeasts makes recycling a non-viable option. Also, some distilling regulations does not allow additional inputs such as enzymes during the distilling process. As such, the use of the right yeast strain suitable for the substrate being used is a key requirement in distilling.

### 3.2.3 Yeast in Ireland

In Ireland, commercial yeast production is not yet well established to service the brewing and distilling sector. This can be attributed to the absence of sugar processing industry in Ireland [24, 25], hence no molasses on which commercial yeast can be grown. Yeast propagation however, is gaining prominence across the brewing sector in Ireland. Some breweries in Ireland propagate their own yeast but not all breweries have the facility or capacity to do this. For those breweries and distilleries that do not propagate their own yeast, they all rely on imported yeasts for their wort fermentation and alcohol production. With the recorded growth of beer and spirits production in Ireland, the demand for yeast is expected to proliferate and therefore, it is necessary to provide new alternatives that can meet industry demands.

## 3.3 Hop

Hop is primarily used in brewing for flavour and aroma development. The world production of the hop stands at about 80,000 to 100,000 tonnes per annum. The US and Germany are the world's largest producers of hop with outputs of 50,820 and 48,500 tonnes respectively in 2019 [26]. In the EU there are about 2,600 farms growing hops with annual output of approximately 50,000 tonnes. This covers about 26,500 hectares which is sixty per cent of the total world land area used for hop cultivation [27]. Hops are grown commercially in 14 countries in the EU with Germany, Czech Republic, Poland, and Slovenia as the major producers. There are different hop varieties used in brewing and these are classified based on the level of  $\alpha$ -acids and essential oils as either bittering hops or aroma hops [28]. The bittering hops are further classified as bittering hops, high  $\alpha$ -variety or super high  $\alpha$ -variety based on the level of the  $\alpha$ -acid. While the aroma hops are further classified as aroma hops and fine aroma hops based on the level and characteristics of the hop oil [28]. According to Almaguer et al. [28], commonly traded bittering hop varieties across the world include Hallertauer Magnum, Hallertauer Taurus, Herkules, Galena, Nugget, Millennium and CTZ (Columbus, Tomahawk, Zeus). While Steinberg [28] listed Hallertauer Perle, Hallertauer Tradition, Spalter Select, Hallertauer Mittelfruh, Hersbruck Hersbrucker, Tettnang Tettnanger, Saaz and Cascade as commonly traded aroma hop varieties.

### 3.3.1 Hop in Ireland

Historically, ale beer was produced in Ireland without hop addition because hop plant is not a native plant in Ireland. Now, a number of breweries in Ireland are attempting to grow their own hops just to serve the hop needs of their breweries [29]. The first attempt at growing hops in Ireland started in the 1960s in a bid to provide Irish brewers sufficient indigenous raw materials for their craft [30]. Towards the tail end of 1990, hop growing in Ireland became less profitable as the macro breweries realised it was cheaper and profitable for them to import larger quantities of hops. As a result, at the start of the 21<sup>st</sup> century, farming of hops in Ireland was beginning to die down. However, with the boom of micro and craft brewing enterprises, growing hops is now on the increase in Ireland. This is mostly fuelled by the need to meet the demands of the brewing and distilling sector for local and sustainably sourced ingredients. There are now a few commercial hop growing companies in Ireland. One example of these is the Wicklow Wolf Hop Farm, which has been credited by Dublin Chamber of Commerce as the first farm in Ireland to grow their hops for commercial purposes. Hops used in Irish breweries are available as whole hops (the whole dried cone), hop pellets (dried hop cones that has been pelletised – reduced in size) or hop extract (pure resin extract containing the hop acids and essential oils) but most microbrewers in Ireland use hop pellets [29]. Therefore, there is a niche that still needs to be filled for commercial hop growing in Ireland and presents a potential venture. At present, the major hop growers in Ireland, Wicklow Wolf Black Perle Porter are growing six varieties – Cascade, Perle, Bramling Cross, Chinook, First Gold and Nugget. Andrew Douglas in 2016 started a hop-growing initiative in Ireland known as the Social Hops Project [30]. The Social Hops Project is a community hop-growing project which aims at showcasing the need for increased local production of hop in Ireland. The project encourages and supports local hop growers in Ireland by helping them build a social circle and providing a market for the hops as soon as they are harvested. Also, craft brewers are teaming up with one another to bear the cost of hop growing in order to create a supply of Irish hops [30].

## 3.4 Water

Water is a significant raw material for brewing and distilling, and a great deal of importance is attached to water supply and treatment especially in the citing of breweries and distilleries [31]. Historically, breweries and distilleries were cited in areas with access to good water supplies [32].

In brewing, water use usually ranges between four to seven litres of water to one litre of beer. Some breweries in a bid to become more efficient in their water use are now aiming for two to three litres of water to one litre of beer. According to *Perry and De Villiers* [33], the average water use in brewing operations is correlated to beer production capacity. In practice, macro breweries tend to utilise water more efficiently than the microbreweries. This is because of well-established water efficiency and water recovery/reuse schemes in macro brewery facilities. Developments in water treatment processes have increased the scope of water supplies. These water treatment protocols aim to provide the required water quality for different unit operations in brewing.

For distilleries, a major aspect of its operation is water distribution through the various processes which entails addition and removal of water at various points in the distilling process. For example, the mashing process requires water addition, while water is removed during wort distillation with another addition of water during maturation. Water for distilling added before the distillation process do not have to meet the stringent water quality specifications under the European Council Directive 98/83/EC [34] provided the water is clean and will not interfere with the final product safety requirements. However, any water added to the distillate after the distillation process such as dilution water, must meet the drinking water requirements as contained in the European Council Directive [34]. In general, the water supply for distilling water should be clean, colourless, and free from contamination.

### 3.4.1 Water use in the Irish brewing and distilling sector

Water utilisation is a key aspect of sustainability in the Irish brewing and distilling sector. In brewing, the water to beer ratio is an indicator of environmental performance. The generally accepted water to beer ratio across the sector which shows a good environmental performance is 4.5:1 [35]. In Irish microbreweries, this is often less considered due to perceived low cost of water [29]. In larger breweries, however, the reverse is the case. A great deal of attention is given to water use and there are strategies in place to either reduce water use or reuse water. In the Irish microbrewing sector, water to beer ratio reportedly goes as high as 10:1, whereas in larger breweries, the ratio goes as low as 2.5:1 [29]. For the microbrewery sector in Ireland, monitoring of water use is very minimal compared to larger breweries. Most microbreweries rely on public mains input meters as opposed to well defined water metering systems in larger breweries. Many distilleries in Ireland are delivering innovations in water conservation which include utilisation of river and rainwater, integrated constructed wetlands to aide water conservation, and a closed loop sealing water system which can save tens of millions of litres of water annually [19, 36]. Distilleries in Ireland with Irish Water customer accounts reportedly use approximately 414,000 cubic meters of water annually [36].

## 3.5 Packaging inputs

Packaging plays a crucial role in product quality and delivery of beer and spirit products including protection and preservation roles for the products. The choice of primary packaging material for beer will depend not just on the suitability of the package for the product but also on marketability and consumer preference/expectations [37]. For example, in Europe, one-third of total beer consumption is draught beer, and in Ireland, this figure goes as high as 80% [37]. As a result, kegging is a prominent beer packaging material including bottling and canning (which is becoming more prominent recently). Larger microbreweries in Ireland have their own kegging and bottling lines while the smaller microbreweries outsource this [29]. Only 30 and 50 litres are used in the Irish beer market, and renting of kegs is a common practice across the sector [29]. However, single-use one-way kegs are gradually replacing steel and aluminium kegs, and these are now widely used across the sector. The single-use one-way kegs are mostly made of recyclable polyethylene terephthalate and works like the traditional keg system using either carbon dioxide draught delivery system or a

compressed flexible plastic bladder [38]. They are also pre-sanitised and ready-to-use by the breweries with no need for any CIP [39].

Another aspect of packaging that is gaining ground in the micro brewing franchise is canning. The use of cans for beer packaging is now becoming more prominent among microbreweries in Ireland. The Independent Craft Brewers of Ireland (ICBI) and the Irish Food Board reported that the number of microbreweries now producing canned beers in Ireland increased from 25% in 2016 to 45% in 2018, almost doubling in number within two years [40]. This can be attributed to the added benefits of can for beer packaging which includes longer shelf-life, enhanced product safety, lighter weight and a more sustainable packaging alternative. There is now a shift in trend from bottling, with canning driving the innovation in packaging for the microbrewery sector. More microbreweries now have a canning line and mostly use cans for their non-kegged products. For the macro breweries, canning is also becoming more popular than bottling because of sustainability issues.

In Irish distilling sector, hundreds of thousands of barrels are being utilised annually with purchases of over 61,000 timber pallets (vast majority purchased from Irish producers), importations of at least 270,000 whiskey barrels from the US, and a maturation capacity of approximately 3.1 million casks across the republic of Ireland [36]. Irish whiskey producers utilise different types of wooden barrels to mature and finish whiskey, and these range from barrels made from American or European Oak to barrels made from chestnut, cherry, acacia, and native Irish Oak. Barrels previously used for American whiskeys are the most common utilised in the sector [36]. The choice of barrel evidently has massive influences on flavour profile of Irish whiskey, and this is one area, Irish distilleries have focused on, in the last decade. The scope available to Irish distillers enable them to diversify the art of finishing whiskey in different barrels for distinct finishes. As a result, utilisation of barrels once used in wines, beer and rum maturation is a common practice across the sector [36].

## 3.6 Energy input

Energy input is a major operating cost, and one of the most significant indicators of the environmental performance of breweries and distilleries [41]. The brewing and distilling process can be very energy intensive, and research suggests that energy is the most expensive operating cost in distilleries [42]. Microbreweries in Ireland use twice the energy utilised in macro breweries per unit of beer produced [29], and this can be attributed to the benefits of scale. The large breweries consume an average of 8 – 12 kWh of electrical energy and 150 MJ of thermal energy per hectolitre of beer while the microbreweries make use of about 20 – 25 kWh of electrical energy and 50 – 75 kWh (220 MJ) of thermal energy per hectolitre of beer [29]. In distilleries, electrical energy makes up 20% of total energy consumption while thermal energy makes up 80% of total energy consumption of which over 90% of it (thermal energy) is utilised in steam generation used in the distillation process [42].

Irish brewers and distillers are beginning to understand the need and implication of energy conservation. Increasing energy costs in addition to existing and emerging global climate issues have all

added to the need for energy conservation in brewing and distilling facilities. Significant energy reduction has been listed by several Irish breweries and distilleries in their corporate sustainability statement as a key production target. More specifically, microbreweries are more aware of the need for energy conservation compared to the need for water management according to a survey by Environmental Protection Agency, Ireland. In general, the sector believes energy efficiency is a key factor in driving competitiveness and environmental sustainability.

#### 4 Sustainability in the Irish brewing and distilling sector

With increased consumer awareness about sustainable production, the Irish brewing and distilling sector has evidently embraced sustainability as a key business strategy [19], with a range of initiatives and developments across the sector. Some of these include minimisation and re-use of carbon dioxide gotten from alcohol fermentation, and implementation of segregation and recycling initiatives to achieve zero waste landfill [19]. The Irish Whiskey Association recently launched a new campaign to profile the sustainability credentials of the Irish whiskey industry with action points such as reducing water usage, supporting barley growth, using renewable energy sources and improving recycling efficiency. The sector in general continues to re-evaluate its mode of operation and raw materials source. Some breweries and distilleries in Ireland are now producing their own renewable energy sources which has seen a drop in the cost of renewable energy in Ireland [43].

Origin Green of the Irish Food Board has been at the fore front of sustainability for food and drinks in Ireland with a verified sustainability programme which breweries and distilleries in Ireland can key into. Under the Origin Green verified sustainability programme, food and beverage companies develop sustainability plans and identify targets in the areas of raw materials, unit operations efficiency, biodiversity measures and social responsibility [44]. This approach offers a form of assistance to breweries and distilleries to identify resource efficiency measures in their operations.

Microbreweries in Ireland are becoming increasingly interested in operating more efficiently and sustainably. In a report by EPA [29], it listed the approaches being used by microbreweries in Ireland to operate more efficiently and sustainably. These include utilisation of indigenous grains, water and heat recovery systems, automated cooling systems and heating elements, energy efficient lighting, energy audit and use of sustainable packaging materials.

#### 5 Conclusion

With the growth of the Irish brewing and distilling sector, sustainable assessment and utilisation of the different processing inputs will translate to sustainable growth of the sector. This includes but not limited to a consistent supply of the right quantity and quality of the different processing inputs and improving efficiency of the unit operations. Sustainability measures for these different inputs is one of the key goals of the sector as evident from the different sustainability initiatives by the sector. While the sector is already

making advances on sustainable production, innovations and new initiatives must keep coming and at the same time be disseminated accordingly for the benefit of the wider value chain. This will not only have an economic advantage for the sector but also, it will safeguard the demands and requirements of the sector especially as it affects product quality and market demands.

#### Author contributions

Ekene C. Umego: PhD Candidate. Writing – original draft.

Catherine Barry-Ryan: Funding acquisition, supervision of PhD, writing – review and editing of manuscript.

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#### Conflict of interest

The authors declare that there are no conflicts of interest.

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