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Sicilian Whey: Utilization of Ricotta Whey in the Production of Value-Added Artisanal Beers

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Abstract: Scotta is an underutilized whey by-product of ricotta making. In this study, we investigated the utilization of scotta in beer production. To understand the quality of regional scotta, samples from eight Sicilian ricotta makers were analyzed for pH, total protein, fat, lactose, titratable acidity, % salt, total plate count, lactic acid bacteria counts, and minerals. Overall, the samples had low amounts of residual protein and fat. The average lactose content was 4.81 g/100 mL $\pm$ 0.52 g, with a pH of 6.12 $\pm$ 0.17 and a salt content of 1.05% $\pm$ 0.24. The majority of lactic acid bacteria counts were below the limit of detection. The total plate counts were more variable, ranging between 10^2 to 10^3 CFU/mL, suggesting occasional post-processing contamination during handling. Scotta was then used to replace some of the water and sugar in the production of two beer styles: (i) a Gose, a salty and acidified German beer style, and (ii) a sweet milk stout. A trained panel used for sensory analysis found that these prototypes fit within the sensory profiles of commercial beers of these styles. This work highlights opportunities to upcycle dairy by-products into novel fermented beverages that would be appealing to consumers.

Keywords: whey; beer; fermentation; upcycling; sensory

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1. Introduction

The reutilization and recycling of by-products of the food and agricultural industry is gaining increased public, commercial, and scientific interest. While a consensus definition of this concept, the circular bioeconomy, is still in debate, an important principle is deriving added value from otherwise wasted outputs from food production [1]. There is a long tradition of valorizing by-products from cheesemaking. In Italy, ricotta cheese developed as a means for local cheesemakers to improve the economic value of their businesses by recovering the protein left in the whey of their cheeses [2]. Ricotta is traditionally made by heating whey, although some producers may now incorporate a little milk, with the addition of salt and acid to coagulate the remaining protein [3]. The ricotta-making process results in its own by-product, called scotta, which is a deproteinized whey with residual lactose and salt [4]. It is estimated that over 1 million metric tons of scotta is produced every year [5], which is commonly used for animal feed [6].

There has been research investigating the development of higher value-added products from scotta like bioethanol for fuel [5], polyhydroxyalkanoates for bioplastics [7,8], and organic acids [9]. While this research is promising, many of these applications require large volumes to be profitable, and thus are likely out of reach for many artisanal cheesemakers who represent important economic contributors to rural communities. The development of beverages from scotta [10] and other whey by-products [11,12] has had some investigation, but the production of such beverages would require significant capital expenditures for processing and packaging equipment for artisanal cheesemakers to effectively produce such beverages.

One possible route for valorizing scotta from artisanal ricotta makers is for these cheesemakers to partner with artisans in other industries who already have investments in processing and packaging equipment that could readily be used to transform scotta into value-added products. One potential partner industry is the craft beer industry. In the past few decades, Italy has seen a renaissance in beer with the growth of beer producers, increasing from less than 50 breweries in 1990 to nearly 700 by 2015 [13–15]. Partnering with a craft brewery provides several benefits for the conversion of scotta into valued-add products. First, the production of beer typically involves a boiling step in the kettle to eliminate any potential spoilage or pathogenic microorganisms [16]. While the production of scotta does include a heat step that would inactivate microorganisms, there is the potential for recontamination of the scotta during cooling and transport; thus, the brewer's kettle provides added assurance that the microbial quality and safety of highly perishable scotta can be maintained. A second benefit of partnering with a brewery is that a brewer is accustomed to utilizing yeast, with and without exogenous enzymes, to convert sugars from various agricultural sources to alcohol [16], and they have the appropriate vessels to control the fermentation. Furthermore, brewers also have the ability to package the subsequent beverage in a wide range of containers such as kegs, bottles, and cans [17]. Lastly, alcohol production and sales are heavily regulated sectors across the world [15], and a partner brewer will know how to navigate these regulations more readily than a cheesemaker.

The use of scotta also provides benefits for the brewery. First, scotta is rich in lactose and as the whey is typically underutilized [4], it could represent a cheap sugar substitute to replace or supplement other adjuncts or grains used in the beer-making process. Secondly, beer production is very water intensive, with estimates that a brewery uses between 4 to 7 L of water to produce 1 L of beer, with 1.2 to 2.3 of those liters being used in the brewhouse alone [18]. Scotta is primarily water, and using it to replace all or a portion of the water demand for making the wort in the brewhouse allows for sustainability improvements to be achieved by both beer and cheese producers. Water quality, including mineral content and taste, is an important factor in beer production. Quality beer cannot be made with low-quality water. Scotta has some potential benefits and drawbacks as a replacement for water. The mineral content of water used for production and in the final beer can vary geographical based on the source of water [16] and by style [19]. Minerals are also intentionally added to water to support enzymes and fermentation, and to achieve specific flavor targets [16]. Calcium levels of 40–100 mg/L are reported to provide clean, dry notes, while chlorides can contribute to the palate, providing an impression of sweetness at lower levels and saltiness at high levels [16]. Other minerals like magnesium, potassium, and sodium can impact the perception of palate fullness, saltiness, bitterness, astringency, and sourness [20]. Whey by-products contain high levels of many of these minerals [21]; thus, the use of scotta could be a way of contributing these minerals and modulating the flavor of the beer. A potential drawback for the use of scotta could be overall taste, as whey products can have strong dairy notes [22]; thus, partial rather than full replacement of water with scotta is the more pragmatic application in beer production.

Research has investigated the use of other lactose-rich dairy by-products, like cheese whey and Greek yogurt acid whey, in the beer brewing process [23,24] and to produce beer-like or wine-like alcoholic beverages [22,25–27]. To date, little research has investigated the specific use of scotta in the production of consumer-facing alcoholic beverages. Furthermore, little research has been conducted incorporating whey streams into specific beer styles, like stout and Gose, that could leverage specific attributes of the whey, such as lactose level or saltiness, and what the subsequent impact is on the sensory of those beers. Thus, the aim of this study was thus two-fold: (i) to understand quality attributes of scotta from Sicilian ricotta makers and (ii) to investigate the incorporation of scotta into the production of artisanal beer styles and to evaluate whether they would conform to the established sensory profiles of those styles.

2. Materials and Methods

To understand the quality of regional scotta, eight Sicilian ricotta makers were selected based on business dimension (small vs. large volume of utilized milk), cheese production (traditional vs. industrial cheesemaking technology), and breed of the animals the milk is produced from (Holstein, Modicana native breed, and mixed), in order to catch the highest variability in scotta composition possible. Samples of milk, whey, and scotta were collected form each farm in March 2019 through February 2021 and were analyzed for the chemical, microbial, and mineral composition.

2.1. Chemical, Microbial, and Mineral Analysis of Scotta

The samples of milk, whey, and scotta were analyzed for pH, protein (%), fat (%), lactose (%), salt (%), titratable acidity, total plate count, lactic acid bacteria count, and minerals. Fat, lactose, and protein were analyzed using mid-infrared spectrophotometry (Milkoscan 6000 FT supplied by Foss Electric, Hillerod, Denmark) according to UNI ISO 9622: 2014. The total bacterial counts were determined by spread plating on Plate Count Agar, incubated at 30 °C for 48 h (UNI EN ISO 4833-1:2022). Titratable acidity was performed according to Soxlet-Henkel (°SH) using acid-base titration with phenolphthalein as an indicator, and the values of titratable acidity were calculated as the volume (mL) of 0.25 mol L^{-1} NaOH that was consumed in the titration of 100 mL of sample (DIN, 10316:2000-08).

Lactic acid bacteria counts were determined on de Man, Rogosa and Sharpe agar (ISO 15214:1998). Salt (%) and chlorides (%) were determined using APHA Standard Methods for the Examination of dairy products 17th ed. 2004 cap.15050 [28]. To determine the mineral contents (chlorides (%), Na (mg/L), K (mg/L), Ca (mg/L), Mg (mg/L), and P (mg/L)) all of the samples were centrifuged at 5000 g for 10 min at 4 °C to separate the suspended materials from the supernatant. An analysis of the mineral content in both precipitates and supernatants was performed by an external laboratory (Istituto Zooprofilattico, Ragusa, Italy) using Inductively Coupled Plasma Mass Spectrometry (ICP e MS, Agilent 7700 Series, Santa Clara, CA, USA).

2.2. Beer Production

2.2.1. Milk Stout Production

The malt bill for the beer was composed of 3.5 kg of pilsner malt, 0.5 kg of brown malt, and 0.5 kg of chocolate malt. All malt was sourced from Monfarm s.r.l. (Lucera, Italy). The milled grains were mashed with 5 L of water and 10 L of scotta. The amount of scotta used was determined in pre-trials based on palatability and brewer's experience. The mash was then transfer to lauter tun and sparged with 12 L of water, with a total of 25 L of wort collected. The wort was transferred to the kettle and boiled for 60 min, with the addition of 20 g and 30 g of cascade hops (Yakima Chief, Washington, WA, USA) at the start of boil and 5 min before the end of boil. A total volume of 22 L with a density of 1.048 and pH of 5.32 was collected at the end of boil. Once transferred to the fermenter, 11 g of the *Saccharomyces cerevisiae* strain LalBrew Voss^{TM} yeast (Lallemand, Montreal, QC, Canada) was pitched and allowed to ferment following the yeast supplier's instructions. The beer was carbonated and then bottled.

2.2.2. Gose-Style Beer Production

The malt bill for the beer was composed of 3.0 kg of pilsner malt (Monfarm s.r.l.). The milled grains were mashed with 14 L of water, 5 L of scotta, and 15 mL of lactic acid. The amount of scotta used was determined in pre-trials based on palatability and brewer's experience. The mash was then transfer to lauter tun and sparged with 13 L of water, with a total of 25 L of wort collected. The wort was transferred to the kettle and boiled for

60 min, with the addition of 20 g of saphir hop (Hopsteiner, Mainburg, Germany) at 30 min. A total volume of 22 L with a density of 1.040 and pH of 5.60 was collected at the end of boil. Once transferred to the fermenter, 11 g of the *S. cerevisiae* strain LalBrew Voss™ yeast (Lallemand, Montréal, QC, Canada) and 11 g of the *Lanchancea* spp. strain Wildbrew Philly Sour™ (Lallemand) were pitched and allowed to ferment following the yeast supplier's instructions. The beer was carbonated and then bottled.

2.3. Beer Analysis

A representative sample of each beer prototype was shipped to Eurofins Food Chemistry Testing Madison, Inc. (Madison, WI, USA) for a sugar profile (SUGN_S) using GC/MS; ethanol analysis (ETOH_VAL_S) following official AOAC Method 983.13; calcium by ICP emission spectrometry (ICP-OES) following AOAC International methods 984.27, 985.01, and 2011.14, and density by gravimetric analysis (SPGP_S).

2.4. Sensory Analysis

The descriptive profile method was used (QDA-UNI EN ISO 13299: 2016) for the sensory characterization. Initial training and familiarization were carried out with the raw materials used in beer production and with examples of Gose-style and milk stout beers from the market. For each beer style, a form with specific attributes was created. The form provided a quantitative evaluation of each descriptor on a continuous scale from 1 to 10, where 10 is the maximum intensity of the attribute.

For the Gose-style beer, six visual, four olfactory, four gustatory, five aromatic, and three tactile descriptors were considered. The stout beer included two further additional attributes for caramelized odor and aroma. Table 1 shows the sensory descriptors evaluated and the references used to define the score values (MIN = 1; MAX = 10) for each attribute. The evaluation was carried out in duplicate for each panel per each type of beer, with 10 trained panelists. The beers with scotta were evaluated within 60 days of their production.

Table 1. Sensory descriptors for scotta-containing beer.

Descriptor		Intensity Score Reference			
Visual	Foam color	1 = pure white	4 = ivory *	6 = cream	8 = cappuccino
	Beer color	1 = straw yellow	4 = golden yellow *	6 = amber yellow	8 = brown
	Clearness	1 = cloudy	4 = veiled *	6 = slightly veiled	8 = clear
Odor	Malt odor	1 = absent	3 = low *	6 = medium	8 = high
	Caramelized odor [a]	1 = absent	4 = low	6 = medium	8 = high
	Vegetable odor	1 = absent	4 = low	6 = medium *	8 = high
	Yeast odor	1 = absent *	4 = low	6 = medium	8 = high
	Animal odor	1 = absent *	4 = low	6 = medium	8 = high
Taste	Sweet	1 = absent	3 = low *	6 = medium	8 = high
	Salty	1 = absent	4 = low	6 = medium *	8 = high
	Sour	1 = absent	4 = low	7= medium*	8 = high
	Bitter	1 = absent	4 = low *	6 = medium	8 = high
Aromatic	Malt aroma	1 = absent	4 = low *	6 = medium	8 = high
	Caramelized aroma [a]	1 = absent	4 = low	6 = medium	8 = high
	Vegetable aroma	1 = absent	4 = low	6 = medium	7 = high *
	Yeast aroma	1 = absent	4 = low *	6 = medium	8 = high
	Animal aroma	1 = absent *	4 = low	6 = medium	8 = high
	Persistency	1 (absent) ≤5 s	4 (low) =5–10 s	5 (medium) =11–20 s *	8 (high) =21–30 s
Tactile	Astringent	1 = absent	3 = low *	6 = medium	8 = high
	Carbonation	1 = absent	3 = low	6 = medium *	8 = high
	Body	1 = aqueous	4 = light *	6 = medium	8 = full

* A commercial Gose beer sample served as the reference for that score for that descriptor. [a] Only the stout was evaluated for these descriptors.

Data collected were analyzed using the statistical software SPSS vers.28 (SPSS Inc., Chicago, IL, USA) and the graphs obtained using Microsoft Excel (Microsoft, Redmond, WA, USA)

3. Results and Discussion

3.1. Survey of Scotta in Sicily

Primary Attributes

While there have been some reviews on the composition and process of ricotta cheese [2], the information is limited and there is little information on the composition of scotta. To address this gap, we surveyed eight Ragusano cheesemakers in Siciliy from March 2019 through February 2021. Samples of the milk used for making the Ragusano cheese, the whey from the Ragusan cheese ready for Ricotta making prior to salt addition, and scotta were taken for analysis (Table 2).

Table 2. Major dairy components (means and standard deviation) of dairy samples from ricotta cheesemaking. Numbers in ( ) indicate the number of samples analyzed for that attribute for that farm over the period from March 2019 through February 2021.

Farm	Sample Type	pH	Protein (%)	Fat (%)	Lactose (%)	Salt (%)	Dry Matter (%)
1	Milk	6.68 ± 0.08 (8)	3.49 ± 0.14 (9)	4.16 ± 0.28 (9)	4.69 ± 0.08 (9)	0.23 ± 0.01 (2)	13.33 ± 0.33 (6)
	Whey	6.59 ± 0.10 (7)	0.79 ± 0.11 (7)	1.15 ± 0.29 (7)	3.44 ± 0.41 (7)	0.69 ± 0.55 (5)	7.42 ± 0.55 (8)
	Scotta	6.24 ± 0.09 (9)	0.50 ± 0.07 (9)	0.41 ± 1.17 (9)	5.31 ± 0.08 (9)	1.31 ± 0.09 (5)	6.16 ± 0.17 (9)
2	Milk	6.69 ± 0.08 (10)	3.15 ± 0.42 (10)	3.61 ± 0.34 (10)	4.42 ± 0.49 (10)	0.26 ± 0.00 (2)	11.80 ± 1.48 (6)
	Whey	6.45 ± 0.11 (10)	0.81 ± 0.13 (9)	1.24 ± 0.11 (9)	3.13 ± 0.30 (9)	0.42 ± 0.35 (6)	7.33 ± 0.70 (10)
	Scotta	6.06 ± 0.04 (10)	0.47 ± 0.05 (10)	0.04 ± 0.05 (10)	5.06 ± 0.17 (10)	1.00 ± 0.14 (6)	6.00 ± 0.19 (10)
3	Milk	6.54 ± 0.33 (10)	3.53 ± 0.16 (10)	4.12 ± 0.40 (10)	4.71 ± 0.06 (10)	0.22 ± 0.05 (2)	13.47 ± 0.21 (6)
	Whey	6.23 ± 0.41 (11)	0.75 ± 0.07 (11)	1.45 ± 0.14 (11)	2.90 ± 0.51 (11)	0.45 ± 0.48 (7)	7.41 ± 0.47 (11)
	Scotta	6.08 ± 0.11 (11)	0.46 ± 0.02 (10)	0.19 ± 0.05 (10)	4.32 ± 0.42 (10)	1.08 ± 0.07 (7)	5.54 ± 0.22 (10)
4	Milk	6.75 ± 0.05 (10)	3.37 ± 0.09 (10)	4.33 ± 1.61 (10)	4.68 ± 0.07 (10)	0.25 ± 0.02 (2)	12.63 ± 0.15 (6)
	Whey	6.52 ± 0.19 (11)	0.91 ± 0.15 (11)	1.19 ± 0.45 (11)	3.44 ± 0.38 (11)	0.46 ± 0.43 (7)	7.76 ± 1.03 (11)
	Scotta	6.27 ± 0.16 (11)	0.67 ± 0.22 (11)	0.54 ± 0.57 (11)	4.63 ± 0.77 (11)	1.12 ± 0.03 (7)	7.04 ± 0.91 (11)
5	Milk	6.67 ± 0.02 (2)	3.63 ± 0.09 (3)	3.51 ± 0.22 (3)	4.52 ± 0.06 (3)	n.d.	12.03 ± 0.77 (3)
	Whey	6.47 ± 0.07 (3)	0.92 ± 0.04 (3)	0.83 ± 0.07 (3)	3.46 ± 0.18 (3)	n.d.	6.80 ± 0.21 (3)
	Scotta	6.25 ± 0.05 (3)	0.59 ± 0.03 (3)	0.06 ± 0.03 (3)	4.58 ± 0.16 (3)	n.d.	5.70 ± 0.14 (3)
6	Milk	6.70 ± 0.06 (4)	3.46 ± 0.05 (4)	4.14 ± 0.17 (4)	4.64 ± 0.03 (4)	n.d.	n.d.
	Whey	6.02 ± 0.91 (5)	0.78 ± 0.06 (5)	1.57 ± 0.09 (5)	2.90 ± 0.28 (5)	0.19 ± 0.02 (5)	7.94 ± 0.16 (5)
	Scotta	6.06 ± 0.11 (5)	0.60 ± 0.02 (5)	0.07 ± 0.03 (5)	5.14 ± 0.08 (5)	1.17 ± 0.21 (5)	6.37 ± 0.09 (5)
7	Milk	6.78 ± 0.04 (10)	3.31 ± 0.08 (10)	3.66 ± 0.14 (10)	4.59 ± 0.09 (10)	0.22 ± 0.01 (2)	12.42 ± 0.35 (6)
	Whey	6.39 ± 0.35 (10)	1.16 ± 0.96 (10)	0.92 ± 0.23 (10)	3.73 ± 0.44 (9)	0.58 ± 0.43 (6)	6.66 ± 2.07 (10)
	Scotta	6.05 ± 0.24 (10)	0.48 ± 0.07 (10)	0.07 ± 0.14 (10)	4.92 ± 0.39 (10)	0.84 ± 0.31 (6)	5.86 ± 0.33 (10)
8	Scotta	5.95 ± 0.12 (5)	0.45 ± 0.07 (5)	0.13 ± 0.09 (5)	4.38 ± 0.19 (5)	0.80 ± 0.32 (5)	5.48 ± 0.27 (5)
All	Milk	6.69 ± 0.17 (55)	3.39 ± 0.24 (56)	3.96 ± 0.76 (56)	4.61 ± 0.23 (56)	0.23 ± 0.03 (10)	12.67 ± 0.91 (33)
	Whey	6.39 ±0.38 (57)	0.88 ± 0.42 (56)	1.21 ± 0.33 (56)	3.28 ± 0.48 (55)	0.47 ± 0.41 (36)	7.35 ± 1.10 (58)
	Scotta	6.12 ± 0.17 (64)	0.53 ± 0.13 (63)	0.22 ± 0.52 (63)	4.81 ± 0.52 (63)	1.05 ± 0.24 (41)	6.08 ± 0.66 (63)

Note: n.d. indicates analysis was not done.

The attributes of the bovine milk used by these Ragusano cheesemakers were aligned reasonably with previous reported surveys of milk components from cows in the area [29], with the variability in components likely due to the seasonality [30,31] and number of samples per farm (Table 2). In 2019, the farms were sampled from March to May, in 2020 from November to December, and from January through February in 2021. Variations in the resulting whey used for ricotta making, and the subsequent scotta, were likely primarily driven by differences in the cheese and ricotta-making processes. Overall, from milk to whey to scotta, a decrease in pH, protein, fat, and dry solids was observed across farms. An increase in salt was observed, consistent with the addition of salt during ricotta making [2]. Interestingly, a reduction in lactose from milk to whey for Ricotta was observed, but an increase in lactose content was observed in the whey vs. scotta. This increase was likely due to the heat step used in ricotta making [2] and the subsequent evaporation of water, resulting in a higher lactose concentration.

When looking at the minor mineral components of both whey and scotta, there were surprisingly not major differences between the samples (Table 3), despite the differences in total salt % observed (Table 2). Interestingly, the mineral levels found in whey for ricotta and scotta were higher than those in other sweet whey from cheeses; for example, whey from Reggiano cheese, with a pH of 6.31, had a lower Ca content of ~43 mg/100 g, P of ~45 mg/100 g, and Mg content of 8 mg/100 g [32]. Others have reported a mineral content in sweet whey of 36.6 mg/100 g Ca, 43.0 mg/100 g P, 6.5 mg/100 g Mg, 45.5 mg/100 g Na, and 123 mg/100 g K [21], which were lower than that observed here. The mineral levels of scotta looked more like those found in acid-type wheys, for example Greek yogurt acid whey with a pH of 4.4 has been reported to have 121 mg/100 g Ca, 66.8 mg/100 g P, 10.6 mg/100 g Mg, 37.9 mg/100 g Na, and 164 mg/100 g K [33]. It is known that as the pH of milk drops, the more colloidal calcium phosphate solubilizes, leaving the casein micelle and ending up in the whey [34], but the whey for ricotta and scotta are not that low in pH. The temperature and time of a heat treatment can also impact mineral solubility, like Ca [35], but it is not clear what mechanism is responsible for the higher mineral content of scotta observed here.

Table 3. Minor dairy components (means and standard deviation) of dairy samples from ricotta cheesemaking. Numbers in ( ) indicate the number of samples analyzed for that attribute for that farm over the period from March 2019 through February 2021.

Farm	Sample Type	Titratable Acidity (°SH)	Chlorides (%)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	P (mg/L)
1	Milk	7.65 ± 0.79 (5)	0.15 ± 0.01 (2)	n.d.	n.d.	n.d.	n.d.	n.d.
	Whey	3.86 ± 1.19 (5)	0.79 ± 0.02 (2)	407 ± 7 (2)	1657 ± 3 (2)	1182 ± 80 (2)	128 ± 4 (2)	958 ± 16 (2)
	Scotta	3.76 ± 0.44 (5)	0.78 ± 0.2 (6)	432 (1)	1645 (1)	1257 (1)	116 (1)	919 (1)
2	Milk	7.60 ± 0.25 (6)	0.16 ± 0.00 (2)	n.d.	n.d.	n.d.	n.d.	n.d.
	Whey	5.48 ± 1.16 (6)	0.52 ± 0.11 (2)	377 ± 8 (2)	1640 ± 1 (2)	1261 ± 4 (2)	129 ± 13 (2)	940 ± 2 (2)
	Scotta	4.89 ± 0.50 (6)	0.57 ± 0.07 (6)	397 ± 20 (2)	1650 ± 1 (2)	1261 ± 1 (2)	129 ± 9 (2)	925 ± 6 (2)
3	Milk	9.59 ± 0.82 (6)	0.13 ± 0.03 (3)	n.d.	n.d.	n.d.	n.d.	n.d.
	Whey	7.56 ± 3.04 (7)	0.71 ± 0.04 (2)	416 ± 20 (3)	1649 ± 7 (3)	1244 ± 6 (3)	124 ± 12 (3)	937 ± 17 (3)
	Scotta	4.98 ± 0.94 (7)	0.70 ± 0.06 (6)	417 ± 35 (2)	1674 ± 5 (2)	1249 ± 25 (2)	129 ± 7 (2)	930 ± 8 (2)
4	Milk	7.59 ± 0.81 (6)	0.16 ± 0.01 (2)	n.d.	n.d.	n.d.	n.d.	n.d.
	Whey	5.45 ± 2.10 (7)	0.67 ± 0.00 (2)	399 ± 10 (2)	1650 ± 17 (2)	1229 ± 11 (2)	134 ± 4 (2)	950 ± 4 (2)
	Scotta	4.92 ± 0.75 (7)	0.71 ± 0.02 (6)	433 ± 34 (2)	1629 ± 7 (2)	1265 ± 13 (2)	127 ± 1 (2)	921 ± 2 (2)
5	Milk	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Whey	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Scotta	n.d.	0.69 ± 0.06 (3)	n.d.	n.d.	n.d.	n.d.	n.d.
6	Milk	7.21 ± 0.55 (4)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Whey	6.78 ± 4.56 (5)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	Scotta	5.00 ± 0.34 (5)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7	Milk	8.49 ± 2.53 (6)	0.14 ± 0.01 (2)	n.d.	n.d.	n.d.	n.d.	n.d.
	Whey	5.50 ± 1.82 (7)	0.55 ± 0.15 (2)	418 (1)	1659 (1)	1247 (1)	131 (1)	938 (1)
	Scotta	4.23 ± 0.69 (6)	0.62 ± 0.15 (6)	396 ± 1 (2)	1664 ± 24 (2)	1255 ± 26 (2)	139 ± 4 (2)	931 ± 12 (2)
8	Scotta	4.98 ± 1.08 (5)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
All	Milk	8.08 ± 1.41 (33)	0.15 ± 0.02 (11)	n.d.	n.d.	n.d.	n.d.	n.d.
	Whey	5.83 ± 2.61 (37)	0.65 ± 0.12 (10)	402 ± 19 (10)	1650 ± 9 (10)	1232 ± 40 (10)	129 ± 8 (10)	944 ± 13 (10)
	Scotta	4.70 ± 0.80 (41)	0.68 ± 0.10 (33)	413 ± 25 (9)	1653 ± 19 (9)	1257 ± 15 (9)	129 ± 8 (9)	925 ± 7 (9)

Note: n.d. indicates analysis was not done.

This opens a future research avenue for scotta, as whey streams that are rich in minerals widen the potential applications in the development of better-for-you non-alcoholic beverages [10]. A 355 mL serving (12 oz) of scotta delivers 446 mg of Ca, which makes it an excellent source of calcium, delivering more than the 20% of 1300 mg daily value (DV) recommended by the US Food and Drug Administration. Calcium deficiency is a challenge globally [36,37] and it is important for bone health [38], highlighting the potential value of scotta utilization. Phosphorous deficiency is not typically an issue, but 355 mL of scotta delivers about 328 mg, also making it an excellent source, delivering more than 20% of the 1250 mg DV. The same serving size of scotta would also deliver 587 mg of K and 46 mg of Mg, making it a good source of both, i.e., more than 10% of the 4700 mg DV for K and 10% of the 420 mg DV for Mg. While salt is used in the production of ricotta, scotta only delivers about 147 mg of Na, about 6% of the DV. Na is important for hydration [39], and its level in scotta is similar to that of sports beverages [40].

The actual cheesemaking process at each farm was not cataloged for this study, but previous surveys of Ragusano cheesemakers note that the natural microflora in the raw milk is allowed to acidify the milk [29], thus it is not unexpected to see total plate counts greater than Log 5 CFU/mL. While there is an initial cooking step of the curd before the removal of whey for ricotta making, the temperature only reaches about 39 °C [29], allowing many bacteria to survive. It is thus expected that the majority of whey samples for ricotta making will have high total plate counts and high counts on MRS (Table 4). In the ricotta-cheesemaking process, the whey is heated to 80–90 °C [2]; at these temperatures, we would expect bacterial die off. The majority of scotta samples were found to be below the limit of detection for both the total plate count and lactic acid bacteria (Table 4). The few that did have counts were relatively low, in the range of 10–1000 CFU/mL. These low counts are indicative of post-process contamination during subsequent handling of the whey. Contamination following heat treatment is not uncommon in other dairy products, like fluid milk [41,42], but a number of pathogens, like *Listeria monocytogenes* and *Salmonella* spp., have been shown to survive or grow in other dairy products with a similar pH and salt content as scotta [43,44]. Proper hygienic practices when handling scotta and downstream kill steps, like pasteurization, are critical for ensuring the safety of beverages developed from scotta. In this study, the goal was the incorporation of scotta into beer making, which involves a boiling stage; this process step along with hygienic handling and storage of the scotta, control for the potential pathogen risk.

3.2. Scotta Incorporation into Beer

3.2.1. Milk Stout

This style of beer is characterized as a dark ale with the addition of lactose [45]. Lactose is not fermentable by the beer yeast, *S. cerevisiae* [46]; thus, lactose is not converted into alcohol and remains in the final beer, providing residual sweetness and body to the beer. This style of beer is typically brewed with pale malt with the addition of caramel and chocolate malts for flavor and color [47]. Ales also tend to have higher levels of Ca than lagers [19]. The use of lactose, calcium levels, and strongly flavored malts were all reasons it was thought this style could lend itself to utilizing scotta. The malt bill for this milk stout was composed primarily of light pilsener malt with some brown and chocolate malt incorporated, with scotta making up 37% of the liquid used in the brewhouse. The final milk stout was 4.0% alcohol by volume (ABV), pH of 4.32, and final density of 1.016 g/mL (Table 5). There was 1.6 g/100 g residual lactose, which was consistent with average scotta lactose concentration of 4.81% ± 0.51% found in our survey (Table 2) and with scotta, making up 37% of the liquid used in the beer. Glucose, galactose, fructose, sucrose, and maltose were all below the limit of detection of 0.1 g/100 g. The calcium level of the milk stout was 14.3 mg/100 g, roughly twice the level report in other stouts and porter beers [19], but lower than the 46.3 g/100 g that would be expected with scotta, making up 37% of the liquid (Table 3). Calcium is an important mineral for yeast metabolism and flocculation, and other studies on the fermentation of dairy by-products with other yeasts have observed reductions in calcium throughout the fermentation [26]. High levels calcium might impart a saltiness to beer; the sensory noted a low to moderate, but not high, level of saltiness in the milk stout with a score of 3.6 (Figure 1).

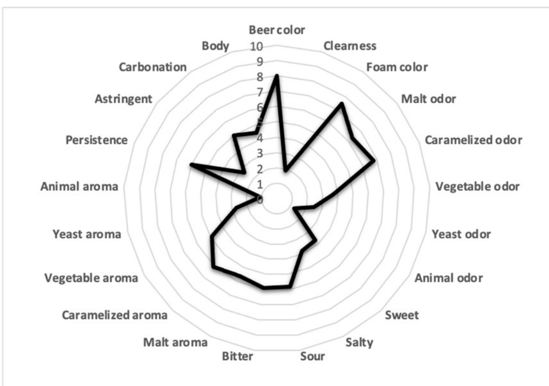
Table 4. Microbial analysis (means and standard deviation) of whey and scotta samples. Numbers in ( ) indicate the number of samples analyzed for that attribute for that farm over the period from March 2019 through February 2021.

Farm	Sample Type	Total Plate Count LOG (CFU/g)	MRS LOG (CFU/g)
1	Whey Scotta	4.9 ± 0.23 (5) 2.3 ± 0.1 (2), b.l. (6)	b.l. (5) b.l. (8)
2	Whey Scotta	6.6 ± 1.3 (5), b.l. (3) 2.6 ± 1.3 (3), b.l. (7)	5.1 ± 1.7 (5), b.l. (3) 2.8 (1), b.l. (9)
3	Whey Scotta	6.1 ± 0.9 (8) 2.8 ± 0.3 (5), b.l. (5)	5.3 ± 0.8 (7), b.l. (1) 1.5 ± 0.2 (2), b.l. (8)
4	Whey Scotta	5.6 ± 1.2 (7), b.l. (1) 2.0 ± 1.0 (7), b.l. (3)	3.3 ± 0.8 (7), b.l. (1) 1.4 (1), b.l. (9)
5	Whey Scotta	5.4 ± 0.3 (3) 2.8 ± 0.0 (2), b.l (1)	4.7 ± 0.0 (3) b.l. (3)
6	Whey Scotta	6.8 ± 0.3 (3) 2.0 (1), b.l. (3)	4.5 ± 0.0 (3) 1.7 (1), b.l. (3)
7	Whey Scotta	6.3 ± 0.3 (4), b.l. (4) 3.1 ± 1 (2), b.l. (8)	4.1 ± 1.8 (3), b.l. (5) b.l. (10)
8	Scotta	2.8 ± 0.8 (4)	1.3 (1), b.l. (3)
All	Whey Scotta	5.9 ± 1.0 (35), b.l. (8) 2.5 ± 0.8 (26), b.l. (33)	4.5 ± 1.3 (23), b.l. (15) 1.7 ± 0.6 (6), b.l. (53)

Note: b.l. indicates samples was below the limit of detection of 10 CFU/mL.

Table 5. Beer with scotta fermentation parameters.

	Milk Stout	Gose
Yeast Strain(s)	*S. cerevisiae*	*S. cerevisiae* *L. thermotolerans*
Original Gravity	1.048	1.040
Final Gravity	1.016	1.004
Apparent Degree of Attenuation	67%	90%
Starting pH	5.32	5.60
Final pH	4.32	3.90
Fermentation Time (days)	25	21
Final Alcohol	4.00%	4.64%



(**a**)

(**b**)

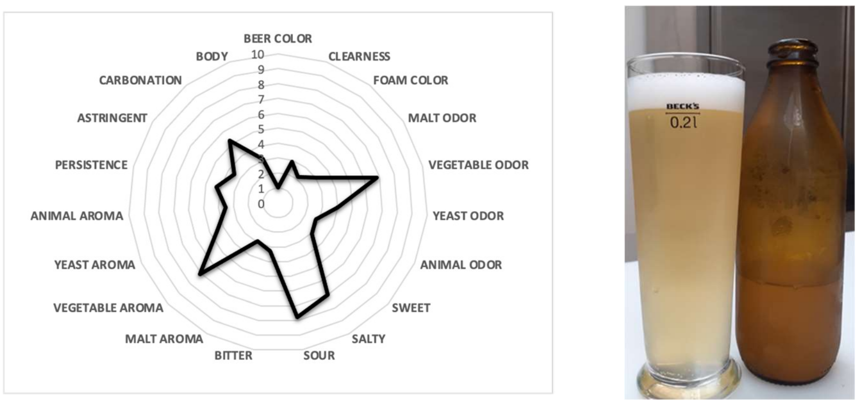
Figure 1. Sensory evaluation of milk stout made with scotta: (**a**) sensory profile of milk stout, mean values and (**b**) visual of milk stout.

A trained sensory panel of 10 participants tasted the milk stout made with scotta and ranked it on a scale of 1 to 10 across 21 attributes (Figure 1a). The milk stout was cloudy and dark brown in color, with a cappuccino-colored foam with a creamy consistency (Figure 1b). The foam was noted to be of low quantity and medium persistence. The most intense olfactory notes were the caramelized ones. A high intensity of coffee, molasses, and chocolate was described. A further note of medium-high intensity was malt. Rather, weaker olfactory notes were vegetable notes that recalled spices, resin, and wood. The predominant flavors were bitter and acid flavors of a medium intensity, with slightly weaker sweet and salty flavors. Aromatic evaluation also described caramelized notes that turned into descriptions of coffee, liquor, and molasses. A malty aroma of medium intensity was quite perceptible. Vegetable aromas were in the form of resin and wood notes. The aromatic complexity had a medium persistence. The tactile attributes of the milk stout were described as a medium body and carbonization level, with a light astringency. These sensory attributes described here align with the reported attributes of other stouts available in the Italian beer market [48], and suggest that a milk stout produced with scotta would be acceptable to consumers and meet their expectations of the beer style.

3.2.2. Gose-Style Beer

This style of beer is described as being a hazy light straw to medium amber in appearance, tart, with a light mineral quality from the addition of salt [49]. The tartness in the beer is due to fermentation by lactic acid bacteria [49]. To our knowledge, there has not been a survey of the actual level minerals in Gose, it was thought that the incorporation of scotta could compliment this style because of the saltiness and upstream presence of lactic acid bacteria. In this case, scotta was used to replace 16% of the water. Gose is typically brewed from a blend of light barley malt and wheat malt [47]; in this work, the Gose-style beer was produced using only pilsner malt. While the scotta does have some lactic acid, the pH of commercial Gose-style beers is typically below 4.0 [49]. That acidity is traditionally due to lactic acid bacteria fermentation before *S. cerevisiae* alcoholic fermentation. In this brew, a co-fermentation of *S. cerevisiae* with a *Lachancea* spp. was used to develop the alcohol and acidity. *Lachancea* spp. are lactic-acid producing yeast that have become popular as a replacement for lactic acid bacteria because yeast are easier to manage in the brewery than bacteria [50,51]. Neither of the yeasts can ferment lactose, and the Gose-style is highly attenuated [49], so lactase was added to hydrolyze the lactose into glucose and galactose that could be utilized by the yeast. Our final beer had an ABV of 4.64%, pH of 3.9, and a final density of 1.004 g/mL (Table 5). Glucose, galactose, lactose, fructose, sucrose, and maltose were all below the limit of detection of 0.1 g/100 g. The calcium level was 7.06 mg/100 g, at the high end for many beers [19].

As with milk stout, a trained sensory panel evaluated the Gose-style beer made with scotta on a similar scale, but across 19 attributes not 21 (Figure 2a). The beer was a pale straw yellow in appearance, with a veiled clarity (Figure 2b), keeping with the style [49]. It had a light, white foam with a creamy consistency, but was poor in quantity and in persistence. The most intense olfactory notes were vegetal ones, characterized as spicy, hops, and citrus fruits followed by weaker notes of malt and yeast and a light animal note of rennet. The predominant flavors of the beer were sour and salty, it lacked sweetness and bitterness, again consistent with style [49]. The main aromatic descriptors were vegetal notes, with hints of hop and spice being quite perceptible, as well as a note of yeast. There were weak malt and rennet notes (animal aroma). The aromatic complexity was of a medium persistence. Concerning tactile characteristics, the Gose-style beer was perceived as having a very light body, medium carbonation, and a low astringency. Overall, the attributes of Gose-style beer with scotta aligned with those previously described for the style [49]. The Gose-style beer was a lighter, less aromatically intense beer than a milk stout, and thus flavor defects were potentially more noticeable. For example, the animal odor and aroma, which may be related to scotta, were more pronounced in the Gose-style beer than in the stout, at 2.8 and 3.5 vs. 1.3 and 1.1 in the stout (Table 6), respectively, even though the scotta made up a higher percentage of the liquid in the stout. This sensory evaluation was performed with trained panelists, and the animal notes were still not the most pronounced notes in the Gose-style beer, but for commercialization it would be important to perform acceptance testing with regular consumers to ensure such sensory notes were not detrimental. The type of yeast used to ferment the whey can have a major impact on reducing dairy aroma and flavors found notes that consumers might find objectional [22]. A wide variety of traditional and non-traditional yeast strains are used in brewing and can modulate flavor compounds in different ways [52,53]; further research is necessary to understand how these microorganisms might positively or negatively impact the flavor compounds in various whey streams during fermentation.



(**a**) (**b**)

Figure 2. Sensory evaluation of Gose-style beer made with scotta: (**a**) sensory profile of Gose-style beer and (**b**) visual of Gose-style beer.

Table 6. Sensory scores (means and standard deviations) for beers made with scotta.

Descriptor	Milk Stout	Gose	Reference *
Beer color	8.0 ± 0.3	1.0 ± 0.1	4.0
Clearness	1.9 ± 0.3	2.9 ± 0.3	4.0
Foam color	7.5 ± 0.4	2.2 ± 0.6	4.0
Malt odor	6.3 ± 0.2	3.08 ± 0.3	3.0
Caramelized odor	6.8 ± 0.6	n.d	n.d.
Vegetable odor	3.7 ± 0.4	6.8 ± 0.3	6.0
Yeast odor	2.5 ± 0.4	4.0 ± 0.2	1.0
Animal odor	1.3 ± 0.5	2.8 ± 0.4	1.0
Sweet	3.7 ± 0.3	3.1 ± 0.2	3.0
Salty	3.8 ± 0.2	7.0 ± 0.3	6.0
Sour	5.8 ± 0.4	7.8 ± 0.2	7.0
Bitter	5.9 ± 0.3	3.3 ± 0.2	4.0
Malt aroma	5.6 ± 0.5	2.92 ± 0.3	4.0
Caramelized aroma	6.1 ± 0.4	n.d.	n.d.
Vegetable aroma	4.9 ± 0.4	7.1 ± 0.3	7.0
Yeast aroma	2.7 ± 0.4	4.4 ± 0.2	4.0
Animal aroma	1.1 ± 0.2	3.5 ± 0.2	1.0
Persistence	6.0 ± 0.4	4.3 ± 0.4	5.0
Astringent	2.7 ± 0.4	3.5 ± 0.4	3.0
Carbonation	5.0 ± 0.4	5.3 ± 0.3	6.0
Body	4.5 ± 0.5	3.1 ± 0.1	4.0

Note: n.d. means evaluation of the attribute was not conducted. * The reference beer was a commercial Gose and the values indicated are the reference score used to train the panelists.

4. Conclusions

Deriving added value from current dairy by-products is important to improve both the environmental and economic sustainability of dairy food producers, large and small.

This study had two primary goals: (i) survey the scotta from several ricotta cheesemakers to better understand the attributes of this by-product, and (ii) evaluate the potential use of scotta in the beer making process to create value-added products. Our survey found that scotta is a fairly consistent by-product with near neutral pH (6.12), that is salty (~1%), with a fair amount of lactose (4.81%) and little protein or fat. Interestingly, scotta appears to have a higher amount of minerals, like Ca, than other sweet whey by-products. The high mineral content of scotta means it is a potential substrate for the development of non-alcoholic hydration beverages that are increasingly in demand by health-conscious consumers. Given the attributes of scotta, proper hygienic handling and process controls will be important to ensure the safety of such products. This work has shown that scotta can be successfully incorporated into beer to add fermentable or unfermentable sugars, increase the mineral content, and replace 16–37% of the water used in the brewhouse. Both the milk stout and Gose-style beer produced with scotta delivered the sensory attributes expected of these styles. Future work is needed to understand consumer perception of reutilization of dairy by-products in beverages and the sensory acceptance of such products by the average consumer. This work highlights the potential for further developing the circular bioeconomy for the dairy and beverage industries.

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Conflicts of Interest: Authors (Catia Pasta, Margherita Caccamo, etc.) were employed by the CoRFiLaC. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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