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Comparative Analysis of Wastewaters from Three Bulgarian Dairy Multiproduct Plants

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HIGHLIGHTS

- Whey and wash waters from three dairy multiproduct plants are studied.
- Effluents are compared by TS, TSS, active reaction, FOG, BOD, COD, TN and TP values.
- Kashkaval whey from sheep's milk processing is the most contaminated fraction.
- Wash waters are cleanest dairy effluents but have largest volumetric load.

Abstract: The growing sector of dairy industry in Bulgaria leads to large waste stream formation with high pollution variation, which require specific treatment application. In the present research different fractions and wash waters from the production of kashkaval and white brined cheese, milk curd, strained yoghurt manufactured in three medium-type Bulgarian milk processing plants were studied. The basic indicators for wastewater quality: total solids (TS), total suspended solids (TSS), active reaction, fat, oil and grease (FOG), 5-day biological oxygen demand (BOD_5), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP) were analysed by standard procedures. The obtained results indicate that kashkaval whey from the sheep's milk processing was the most contaminated effluent, reaching COD more than 68,000 mg O_2/dm^3 and BOD_5 – up to 37,000 mg O_2/dm^3. Such high concentrated wastewaters can be treated only by anaerobic methods. Secondary cheese whey (SCW) has less impurities than cheese whey, but its soluble milk fractions are difficult to biodegrade, resulting in BOD_5:COD ratio lower than 0.40. Application of membrane technologies in milk co-product processing remove totally FOG from the SCW, where BOD_5 and COD values are around 950 and 2.500 mg O_2/dm^3, respectively. However, the TN concentration in it is not enough to apply directly aerobic utilization. This method is the most appropriate for washing waters, which occupy both the largest volume and the cleanest fractions of all milk effluents. Future combinations of different dairy wastewaters will show the best utilization protocol for each of the milk processing plant.

Keywords: industrial dairy wastewater composition; whey; second cheese whey; washing water.

INTRODUCTION

The dairy industry has deep traditions in Bulgaria [1]. In recent years, a positive trend in the consumption of dairy foods has been observed in the domestic market [2,3]. The production of white brined cheese, kashkaval and Bulgarian yogurt is the most represented, but the variety of products offered is increasing [4-9].

Moreover, this sector is one of the main consumers of drinking water in the food industry [10,11]. The large assortment and applied technologies lead to the production of waste streams of different quantity and quality [12,13]. A good knowledge of the composition and characteristics of waters creates a prerequisite for their correct treatment [14]. The most polluted are the waste streams from the production of white brined cheese, kashkaval, cottage cheese, condensed milk and others, which are often thrown away without further treatment [15]. No less significant are the washing waters obtained from the cleaning of the technological equipment [16]. The main pollutants in them are organic compounds such as lactose, water-soluble proteins, emulsified lipids, mineral substances and detergents, which are the cause of high values of BOD, COD, insoluble solids, nitrogen compounds [17-20]. The rapid decay of the large amount of organic matter can create problems when processing these wastewaters in urban treatment plants, and their direct discharge into surface water bodies is highly undesirable [21,22]. Therefore, it is necessary to look for opportunities for their purification before release into the environment. The presence of different components in the wastewater of the dairy industry requires the application of a multi-level treatment approach [23]. Despite studies in the field, published data on the composition of industrial wastewater from dairy plants are few [24-28], and for Bulgaria – the information is insufficient [29].

The purpose of the present study is to characterize the waste streams from the production of white brine cheese, kashkaval, milk curd, yoghurt and strained yoghurt from various plants in Bulgaria.

MATERIAL AND METHODS

Material

Whey and washing waters from three medium-type milk processing plants (production capacity less than 100 m^3 raw milk/day) located in the region of Southern Bulgaria were studied. The first two enterprises manufacture 12 months of cow's milk and 5 months of the year sheep's milk into kashkaval, white brined cheese and whey curd obtained by filtering through cloth - for Plant 1 (P1) and through membrane processes - for Plant 2 (P2). The third factory (P3) specializes in the production of yoghurt, strained yoghurt and milk curd.

Data from the flow meters for the volume of the milk processed and waste effluents was kindly provided to us by the respective dairy plant operators.

Sampling was carried out in accordance with current legislation [30]. The number of annual measurements is 4 – for P1; 2 – for P2 and 4 – for P3. During the analyses, an average sample obtained from pre-homogenized, consecutively obtained 4 single samples taken at an interval of 2 h was used.

Methods

The determination of the individual parameters of the wastewaters was carried out according to the specified standards: total solids (TS) and total suspended solids (TSS) - BSS 17.1.4.04:1980 [31], active reaction - BSS 17.1.4.27:1980 [32], fat, oil and grease (FOG) – EPA 1664 [33], 5-day biological oxygen demand (BOD_5) – ISO 1899-2:2004 [34], chemical oxygen demand (COD) – ISO 6060:2020 [35]. The following chemical indicators were analyzed photometrically by tests from the Spectroquant® series, Merck Millipore, USA: total nitrogen (TN) – EN ISO 11905-1 [36] and DIN 38405-9 [37], total phosphorus as orthophosphate (TP) – EN ISO 6878:2005 [38].

Statistical processing of the data

All wastewater analyzes were performed in triplicate. The results obtained were summarized by determining the mean value and standard deviation (± SD). Data processing was performed using the MS Office Excel 2010 software product.

RESULTS AND DISCUSSION

Whey from the production of kashkaval and white brined cheese

Regardless of the type of end product, cheese production can be summarized in the following basic steps [39]. After removal of mechanical impurities and standardization in terms of casein and fat content, the milk is pasteurized and sent for biological ripening in stainless steel vessels. Subsequently, it is sent for curdling under the influence of a milk coagulating enzyme. After the required technological time, the resulting coagulum is formed, pressed, salted and matured, packaged and turned into a commercial product [40,41]. The waste liquid component is referred to as whey [42].

In Table 1 the results of the study of whey formed during the production of Bulgarian white brined cheese and kashkaval from cow's and sheep's milk in P1 and P2 are presented. The obtained data is compared with the permissible standards for discharging industrial wastewater from the dairy industry into surface runoff water bodies [43].

The amount of separated whey in the different plants is similar - 75-90% from the volume of incoming milk, with average levels for cheese production 85-90% [44-46]. More whey is formed in the production of kashkaval than that of white brined cheese. The values are 11% higher when the raw material for kashkaval is sheep's milk and 3-10% higher – from cow's milk.

TS in the whey exceed 50 g/L [47], while TSS show wide variations for individual products, with the largest difference in the production of cow's milk cheese. Their content relative to TS is higher in sheep milk streams - 45% more for cheese whey in P1 and 14% - than the same in P2. Whey from P2 is richer in water-insoluble compounds in comparison with that of P1. In all cases, the TSS exceed the permissible values for discharge into water bodies by more than 99%.

Active reaction is important for the proper operation of water treatment processes [48,49]. The data report a typical slightly acidic environment [50] that prevails in whey from kashkaval production compared to that from white brined cheese. It is the lowest for cheese from cow's milk in P1: 5.28 pH units. According to Regulation 6, the specified indicator is in the standards only for whey from white brined cheese from sheep's milk. The low pH value and the high content of water-soluble components, such as lactose, can result in rapid spoilage of whey, which adversely affects its subsequent biological treatment [41,45,51].

In dairy wastewater, compounds with lipid nature are undesirable in concentrations above 10 mg/L [43]. Larger values pose risks of clogging the pipes in the sewage system or disrupting the aerobic environment during degradation of the different dairy pollutants [52,53]. The FOG content is higher in the whey from the kashkaval production and in raw sheep's milk (Table 1). The probable reason can be the fatter sheep's milk compared to cow's [54]. Fats predominated in the whey of P2 - an average of 501 mg/L, or 30 mg/L more than P2. It was highest in the waste streams of sheep's kashkaval - 750 mg/L, and lowest - for white brined cheese from cow's milk - 310 mg/L, respectively 75 and 31 times above the permitted values [43].

The choice of wastewater treatment methods directly depends on BOD_5 and COD concentrations [55,56]. The prevailing limit for wastewater from food processing plants under BOD_5 is 50 mg/L, while for COD it is 250 mg/L [43]. Among all waste streams from the dairy industry, cheese whey is the most loaded by these indicators [46,47], with values of BOD_5 – 19,000-35,010 mg/L and COD – 54,100-68,300 mg/L which is 99% more than Bulgarian laws allow. Whey from sheep's milk is more contaminated than the same from cow's milk - on average 3.7 times more by BOD_5 for P1 and 2.7 times more by COD for P2. The high concentration of these pollutants in whey attracts the attention to use anaerobic methods for their utilization [57-59].

The BOD_5:COD ratio is important for proper determination the level of biodegradability and the technological features of wastewater treatment [60]. If it is above 0.5-0.6, the water can be purified biologically [61]. For P1, only kashkaval whey from sheep's milk ($K^{SM}{}_1$) met the above requirements with a value of 0.51, but for P2 it was achieved both at kashkaval whey from sheep's milk ($K^{SM}{}_2$) - 0.54 and yellow cheese whey from cow's milk ($K^{CM}{}_2$) - 0.61. The results for the other types of whey exceed 0.3. This indicates that they must be purified physico-chemically before they can undergo biological treatment methods [62].

Wastewater TN and TP are related to eutrophication processes in water basins [20,63]. All samples analyzed show that these biogenic elements exceed many times the emission norms [43]. Greater concentrations of TN were found in raw sheep's milk, in the production of kashkaval and in P2. The indicated conclusions do not apply to TP. The least polluted in terms of TN and TP is white brined cheese whey from cow's milk manufactured in P1 ($WBC^{CM}{}_1$), with 180 mg/L and 37 mg/L, respectively. The maximum load for TN is $K^{SM}{}_2$ – 5,320 mg/L, while for TP is $K^{CM}{}_1$ - 620 mg/L.

The COD:N ratio is critical for proper operation of anaerobic systems. 40:1 is considered as optimal value, although other authors share the successful operation of reactors at 80-160:1 [64,65]. Only three of the tested whey samples approach the optimal characteristics - $K^{SM}{}_1$ - 41:1, white brined cheese whey from sheep's milk manufactured in P1 ($WBC^{SM}{}_1$) - 53:1 and $K^{CM}{}_1$ - 131:1. Carbon compounds predominate in $K^{CM}{}_1$. Whey from P2 has high concentrations of nitrogenous compounds - COD:N varies 13-22:1, which can create conditions for NH_3 formation and poses a risk of inhibiting biogas fermentation [66].

In well-functioning anaerobic plants, COD:P is 80-200:1 [65]. Only $WBC^{CM}{}_1$ is outside the specified limits with a value of 1487:1.

Table 1. Characterization of whey from yellow and white brined cheese

Indicator	Unit	K^{SM}_1	K^{SM}_2	K^{CM}_1	K^{CM}_2	WBC^{SM}_1	WBC^{CM}_2	WBC^{CM}_1	WBC^{CM}_2	Permissible values [43]
Whey:milk	m^3/m^3	0.84	0.85	0.87	0.90	0.75	0.76	0.84	0.81	-
TS	mg/L	69,300±620	67,500±400	65,500±621	63,500±451	57,050±225	54,200±400	62,000±721	52,800±511	-
TSS	mg/L	34,210±330	35,110±201	17,780±211	28,580±151	24,080±145	24,620±312	21,000±264	22,000±205	50
Active reaction	pH	5.60±0.02	5.60±0.04	5.28±0.05	5.61±0.04	6.03±0.05	6,05±0.05	5.60±0.12	5.80±0.05	6.0-9.0
FOG	mg/L	545±55.8	750±58.2	510±565.0	530±33.0	445±55.2	415±22.5	380±56.0	310±48.0	10
BOD_5	mg/L	35,010±250	37,100±223	19,590±211	33,200±200	27,270±442	26,400±99	19,000±191	24,089±59	50
COD	mg/L	68,300±751	68,108±100	63,000±751	54,100±105	57,000±338	62,200±126	55,000±481	55,440±66	250
TN	mg/L	1,650±54.0	5,320±64.0	480±23.5	3,280±15.5	1,080±44.5	2,996±50.5	180±25.0	2,480±15.0	10
TP	mg/L	380±35.0	399±25.8	620±22.2	425±23.8	364±11.5	369±19.0	37±4.0	302±2.0	2
BOD_5:COD	-	0.51	0.54	0.31	0.61	0.48	0.42	0.35	0.43	-
COD:TN	-	41:1	13:1	131:1	16:1	53:1	21:1	306:1	22:1	-
COD:TP	-	180:1	171:1	102:1	127:1	157:1	169:1	1487:1	184:1	-

Dairy plant 1: K^{SM}_1, K^{CM}_1 – kashkaval whey from sheep's and cow's milk, respectively; WBC^{SM}_1, WBC^{CM}_1 – white brined cheese from sheep's and cow's milk, respectively; Dairy plant 2: K^{SM}_2, K^{CM}_2 – kashkaval whey from sheep's and cow's milk, respectively; WBC^{SM}_2, WBC^{CM}_2 – white brined cheese whey from sheep's and cow's milk, respectively; TS – total solids, TSS – total suspended solids, FOG – fat, oil and grease; BOD_5 – biological oxygen demand for 5 days; COD – chemical oxygen demand; TN – total nitrogen; TP – total phosphorus

Secondary whey from the production of kashkaval and white brined cheese

Whey is a secondary product in the kashkaval and white brined cheese manufacturing [67]. It is often used as a raw material for obtaining other dairy products [68]. The fat is separated from the whey, while residual proteins are filtered through a cloth or membrane resulting whey curd [47,69]. The waste permeate forms the so-called second cheese whey (SCW) [70]. Although the last is most commonly disposed of in waste streams, it is less studied than whey [47,71].

In Table 2 the results of the characterization of SCW obtained during the production of cottage cheese by filtration through cloth in P1 and through a membrane in P2 are summarized. The volume of SCW is similar in the different industries – on average about 0.91 m^3/m^3 of milk.

Tatoulis, 2014 summarized that the TS concentration in the SCW did not differ from that in the whey [71]. Our results support the mentioned statement. However, the data from Table 2 shows a decrease in this indicator, which for P1 is in the range of 5-23.5%. The probable reason for the wide range of the TS reduction is due to the different types of raw materials being processed – sheep's kashkaval and white brined cheese whey (SCW^{SM}_1) and cow's cheese whey (SCW^{CM}_1). In P2, where curd is produced by means of membrane retention of whey proteins, the reduction of TS exceeds 92%. One of the biggest advantages of membrane technologies over cloth filtration is the ability to retain smaller protein fractions, resulting in cleaner waste streams [71]. In support of this statement, the lower amounts of suspended matter in the SCW are visible. Their concentration in SCW_2 is over 87% less than that in Plant 1.

The active reaction of SCW is more acidic than whey [71]. In the SCW from P2 (SCW_2) it reaches 5.81, while for P1 it is about 4.55 pH units.

The higher fat content of sheep's milk is reflected in the quality of the SCW. FOG in SCW^{SM}_1 is 305 mg/L, which is 30 times higher than the permissible values or 59.7% more than the same in SCW^{CM}_1. But not found in SCW_2. By retaining milk fats, membrane technologies contribute to shortening the technological steps in the treatment of dairy wastewater [72,73].

Undoubtedly, BOD and COD most strongly influence the selection of appropriate technologies for processing waste streams [74]. High values of these indicators are found for SCW^{SM}_1 and SCW^{CM}_1, making them available mainly for anaerobic processes [47]. But COD at SCW_2 is only 2500 mg/L and BOD_5 is 954 mg/L. Low pollutant concentrations suggest the possibility of using aerobic biological treatment of SCW_2 [73]. However, here BOD_5:COD is around 0.38 – below the 0.5 limit for successful aerobic microbial treatment [75,76]. Furthermore, nitrogen compounds should be about 1:20 of the biodegradable pollutants [77,78], and here BOD_5:N is 119:1. The lack of N in combination with rapidly digestible BOD in the form of lactose can lead to fast development of filamentous microorganisms during wastewater treatment processes. This disrupts the formation and proper separation of activated sludge [79-81]. COD:N is about 312:1, which exceeds the possibilities for normal development of methanogenic bacteria [64,65]. An analogous conclusion can be drawn for SCW^{SM}_1 and SCW^{CM}_1, where this ratio is even higher.

The TP content in SCW from the different productions is similar. It is highest in SCW^{SM}_1 – 32 mg/L, followed by SCW_2 – 28 mg/L and SCW^{CM}_1 – 21 mg/L. The membrane technology implemented in P2 does not help to reduce phosphate compounds in SCW_2. This requires a TP separation step before discharge. Efficient biological elimination of TP from SCW_2 would be difficult because COD:P = 89:1, about 4.5 times the optimum [82]. Here, other possibilities for its removal should be sought [63,83,84].

Whey from the production of milk curd and pressed milk

Whey can be obtained from other dairy products [85]. In Table 2 the results of an analysis of whey formed during the production of milk curd (MW_3) and strained yoghurt milk (SYW_3) in P3 are described. Compared to the other types of whey, the amounts of MW_3 and SYW_3 are less than half of the manufactured milk. Contamination is closer to the SCW from P1. Significant differences are found in BOD, TN and TP content, which are much higher in P3 effluents.

Strained yoghurt production gives 400 L/m^3 of milk more SYW_3 and more contaminated whey than milk curd processing. The content of TS and TSS is close, with 3.8% more for TS and 5.3% more for TSS in favor of SYW_3. Here, the active reaction is weakly acidic – 5.1, while in MW_3 – 4.7. FOG is 3 times more in SYW_3. It is noteworthy that BOD in MW_3 is lower by 7.8%, but COD exceeds the values in SYW_3 by about 8.7%. The likely reason is related to the presence of more difficult to oxidize compounds in the whey of milk curd. BOD5:COD varies: 0.54-0.58, but suggests that these waste streams are suitable for biological treatment [76]. TN reaches 15,990 mg/L for SYW_3 and 11,320 mg/L for MW_3 and is the highest of all whey samples analyzed. The presence of high concentrations of nitrogen compounds will create a problem in anaerobic fermentation of whey [86,87]. The TP is closer to that in cheese whey, but it is 10 times higher than the same in SCW.

Table 2. Characterization of secondary whey from kashkaval and white brined cheese, milk curd and strained yoghurt

Indicator	**Unit**	**SCW^{SM}_1**	**SCW^{CM}_1**	**SCW_2**	**MW_3**	**SYW_3**	**Permissible values [43]**
Effluent:milk	m^3/m^3	0.90	0.91	0.92	0.38	0.28	-
TS	mg/L	59,900±334	50,100±291	4,990±4	50,008±205	52,006±181	-
TSS	mg/L	9,590±91	7,650±87	980±85	7,200±201	7,600±100	50
Active reaction	pH	4.60±0.15	4.50±0.02	5.81±0.10	4.70±0.05	5.10±0.03	6.0-9.0
FOG	mg/L	305±3,0	122,9±1,8	-	100±5,2	305±20,5	10
BOD_5	mg/L	14,100±880	11,400±261	954±12.6	30,700±201	33,280±301	50
COD	mg/L	51,200±331	41,100±30	2,500±80	57,200±521	52,200±300	250
TN	mg/L	99±8.0	42±2.0	8±0.5	11,320±55.5	15,990±60.5	10
TP	mg/L	32.0±2.0	21±3.0	28±1.0	340±11.8	305±10.5	2
BOD_5:COD	-	0.28	0.28	0.38	0.54	0.58	-
COD:TN	-	517:1	979:1	313:1	5:1	4:1	-
COD:TP	-	1600:1	1957:1	89:1	168:1	188:1	-

Dairy plant 1: SCW^{SM}_1, SCW^{CM}_1 – second cheese whey from (from kashkaval and white brined cheese production) sheep's and cow's milk (from kashkaval production), respectively; Dairy plant 2: SCW_2 – second cheese whey after membrane filtration unit; Dairy plant 3: MW_3 – whey from milk curd production, SYW_3 – strained yoghurt whey

Washing wastewater from the production of kashkaval, white brined cheese, whey and milk curd, yoghurt and strained yoghurt

A large part of the industrial waste streams of the dairy industry is formed by washing waters [88]. According to their purpose, they can be grouped into first wash water (WWI) - after pushing the milk and whey out of the apparatus and second wash water (WWII) - for cleaning the equipment after washing [89]. In Table 3 the values of pollution of the washing waters from the production of kashkaval, white brined cheese and whey curd from P1 (WW^{I}_{1} and WW^{II}_{1}, respectively) and P2 (WW^{I}_{2} and WW^{II}_{2}, respectively), and yoghurt, strained yoghurt and milk curd from P3 (WW^{I}_{3} and WW^{II}_{3}, respectively) are summarized.

In the most of the cases the amount of washing water exceeds the volume of milk. An exception can be made for WW^{I}_{3} where 0.30 m^3 wash water is used per 1 m^3 milk. The common reason is due to the assortment diversity of the products received and the available production technologies. For P2, the wash flows reach 3.66 m^3/m^3 milk, followed by P1 – 2.44 m^3/m^3 milk and P3 – 3.07 m^3/m^3 milk. Also, the first wash waters are less compared to the second wash waters. The difference is particularly large in P3, where WW^{I}_{3} is under 10 % from the total amount of wash water. Here, the main activity is focused on obtaining yogurt, which occupies almost the entire volume of milk, and not only its proteins. While whey are formed only from milk curd and strained yoghurt. Thus, the need for WW^{I}_{3} is minimal as large volumes of whey do not need to be pushed out of the respective production vessels.

In the washing waters of cheese and whey curd, TSS exceed 60%. But in the case of yoghurt production – TSS are a little over 10%.

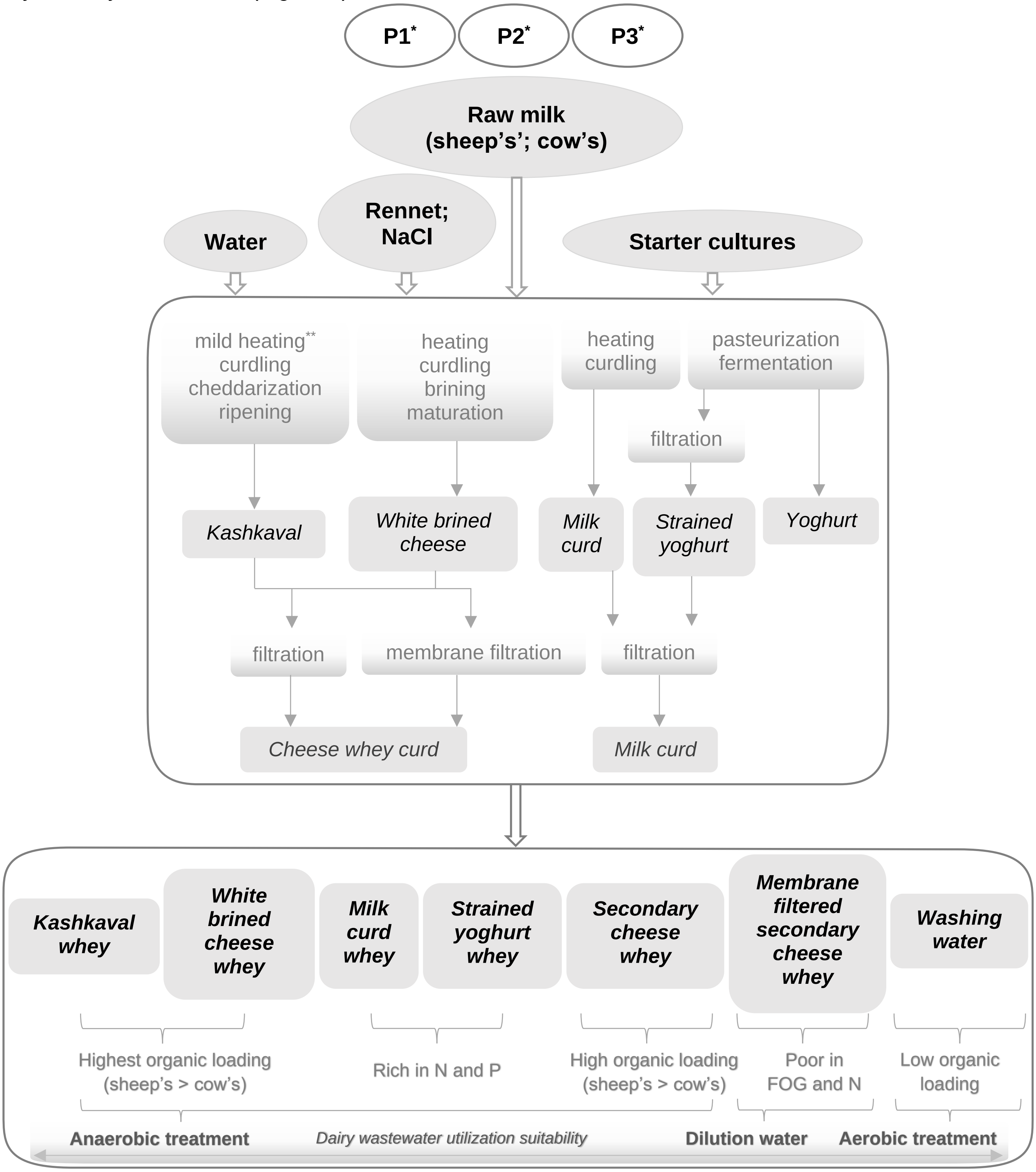
In all plants, the WW^{I} is more polluted than the WW^{II}. The active reaction is above 5. The washing waters from P3 have the lowest pH values – 5.1-5.3, while in P2 they exceed 6.6. FOG are not detected neither in the wash water of P2, nor in WW^{II}_{1}, but in WW^{I}_{3} they are 730 mg/L. In individual streams, BOD_5 varies from 400 to 706 mg/L, while COD – 650 to 1590 mg/L. The low pollution of these wastewaters allows application of aerobic treatment methods [90]. They can be more accessible for P2 and P3 where BOD:COD is over 0.5 [75]. For P1, BOD:COD reaches 0.41-0.42 – here it is necessary to use physicochemical processes first before microbial treatment [76]. In wash waters from P2, no TN is detected, making biological treatment difficult. A possible solution is to enrich these effluents with nitrogen compounds, combine them with domestic waste streams or apply for dilution of highly contaminated dairy wastewaters [91]. Wash waters from P1 and P3 are suitable for aerobic treatment. The high concentrations of FOG, TN and TP in P3 require an approach to separate lipids and eliminate biogenic elements from the waters before discharge into water bodies [92,93].

Table 3. Characterization of wash water from dairy plant 1, 2 and 3

Indicator	Unit	WW^{I}_{1}	WW^{II}_{1}	WW^{I}_{2}	WW^{II}_{2}	WW^{I}_{3}	WW^{II}_{3}	Permissible values [43]
Wash water:milk	m^3/m^3	1.13	1.31	1.74	1.92	0.30	2.77	-
TS	mg/L	1,250±41	905±31	1,100±41	800±21	6,200±100	7,089±51	-
TSS	mg/L	782±65	550±21	760±36	510±30	1,800±103	720±72	50
Active reaction	pH	5.40±0.10	6.22±0.12	6.64±0.52	6.75±0.40	5.10±0.03	5.30±0.03	6.0-9.0
FOG	mg/L	73±3.6	-	-	-	730±53.0	10±0.5	10
BOD_5	mg/L	660±44	450±20	706±9	510±23	700±157	400±185	50
COD	mg/L	1,590±31	1,100±21	1,316±92	985±105	1,200±85	650±61	250
TN	mg/L	69±10.5	20±1.5	-	-	380±11.0	50±1.0	10
TP	mg/L	18±2.0	11±2.0	31±1.0	29±1.8	300±23.0	30±2.0	2
BOD_5:COD	-	0.42	0.41	0.54	0.52	0.58	0.62	-
COD:TN	-	23:1	55:1	-	-	3:1	13:1	-
COD:TP	-	88:1	100:1	43:1	34:1	4:1	22:1	-

Dairy plant 1: WW^{I}_{1}, WW^{I}_{2}, WW^{I}_{3} – washwater after milk and whey removal for dairy plant 1, 2 and 3, respectively; WW^{II}_{1}, WW^{II}_{2}, WW^{II}_{3} – wash water after clean-in-place procedure for dairy plant 1, 2 and 3, respectively

The results of the analyses are summarized with the production technologies in a unified flow diagram, which can serve as a basis for creating a general model for the more effective treatment of waste streams from the dairy industry in the future (Figure 1).



***Legend: P1, P2, P3 – dairy plant 1, 2 and 3, respectively; **Technologies are adapted from [94]**

Figure 1. Simplified flowchart from three Bulgarian dairy multiproduct plants and possible treatment options of derived wastewater streams.

CONCLUSION

Based on the studies carried out, the following more important conclusions can be summarized:

1. No significant differences are found in the waste streams from Bulgarian and foreign milk processing plants.
2. The most contaminated are the whey from the production of kashkaval and white brined cheese with the raw material - sheep's milk.
3. The cleanest effluents are the washing waters, but they fill the largest volume compared to the raw milk.
4. Membrane technologies create conditions for a more complete utilization of the whey, but they reduce the possibilities for biological treatment of the wastewaters coming out of them.
5. Anaerobic methods are more suitable for treating whey, while aerobic methods - for washing waters. Whey and washing waters from the production of yogurt, milk curd and strained yoghurt are more loaded with biogenic elements than those from the production of kashkaval and white brined cheese.

Conflicts of Interest: All authors state that there are no conflict of interest concerning the manuscript "Comparative Analysis of Wastewaters from Three Bulgarian Dairy Multiproduct Plants".

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