OPTIMISATION OF LACTOSE HYDROLYSIS BY COMBINING SOLIDS AND β -GALACTOSIDASE CONCENTRATIONS IN WHEY PERMEATES

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*A detailed study of lactose hydrolysis was conducted using 50, 250 and 500 units of β -galactosidase (*Kluyveromyces lactis* and *Bacillus licheniformis* origin) in acid and sweet whey permeates at different solid concentrations 20%, 30% and 40% (w·v⁻¹). The amount of lactose, glucose and galactose was measured by HPLC – RID. Hydrolysis was carried out at optimal enzyme temperature 42.5 °C for 4 h. Medium pH before hydrolysis was adjusted using 10% KOH. The experimental results were compared taking into account the sugar profiles and experimental conditions. The highest lactose hydrolysis occurred at solid concentration 20% (w·v⁻¹) and at enzyme amounts of 250 and 500 units for both permeates. Using 50 units of enzymes, in many cases the amounts of glucose and galactose were more or less equal in range of 6.5–43 g·l⁻¹ and the hydrolysis percentage was quite low in the range of 2.7–62%. Comparing both whey permeates, a higher hydrolysis percentage (99%) was obtained using acid whey and 500 enzyme units.*

Key words: glucose-galactose syrup, enzymatic hydrolysis, commercial lactase.

INTRODUCTION

More than half of the dairy global facilities treat whey as a waste product that cannot be recycled and transforming into new, high value-added products (Sady *et al.*, 2013). Use of whey was previously underestimated and nowadays is considered as a valuable by-product due to the growing tendency of including valuable components of whey in infant nutrition and as well in dietetic food production (Tanguy *et al.*, 2019). Most often sweet whey is redirected to spray drying to form high-value dairy powders for use in infant formula and sport nutrition applications (Chandrapala *et al.*, 2016). Comparing acid and sweet whey, the content of constituents differs in the concentrations of protein, minerals and lactose, and there are significant differences in the amounts of casein and calcium and acidity (Wronkowska *et al.*, 2018). Both sweet and acid whey have about 94% water and 4.5 % lactose, while acid whey has higher acidity than sweet whey, with medium pH 4.3–5.1 for acid whey and pH 5.9–6.6 in sweet whey (Lindsay *et al.*, 2018).

The dairy industry now has a challenge concerning acid whey. During the last five years, the consumer as well as

market demands have rapidly raised for a variety of acid-coagulated products (curd, cottage cheese, quark), and it is predicted that this trend will continue globally. Moreover, this situation poses a problem of the creation of 1.6 billion litres per year of acid whey as waste (Chandrapala *et al.*, 2015).

Acid whey contains large amounts of lactic acid and salt, which may influence the properties and behaviour of lactose and other whey components during concentration and processing (Zolnere and Ciprovica, 2019). The impact of acid whey composition on processing has not been well studied, making it difficult to find solutions to the present and growing problem (Chandrapala *et al.*, 2015).

Potentially, a part of the produced whey can be used as a base for new product development. Concentrated whey has many benefits. It is rich in composition and adds nutritional and functional value to products (Argenta and Scheer, 2020). While processing of whey is not competitive against existing fermentation process using sugar cane, corn starch and lignocellulosic biomass as substrates, whey fermenta-

tion is nowadays a major focus for high-value products (Sampaio *et al.*, 2019).

Whey and whey permeate fermentation without any pre-treatment is not profitable due to their low lactose content, which means higher costs. On the other hand, dried or concentrated whey and whey permeate could be used for the production of new sugars, because the water content is low and lactose content is high, and are cheap and can be stored easily (Argenta and Scheer, 2020).

In this study, lactose hydrolysis was performed using multiple-unit amounts of β -galactosidase (*Kluyveromyces lactis* and *Bacillus licheniformis*) in acid and sweet whey permeates at different solid concentrations (20%, 30%, and 40% w·v⁻¹). The obtained results can be valuable for dairy facilities that are already producing glucose-galactose syrup or thinking to introduce this process in the near future.

MATERIALS AND METHODS

Materials. NOLA Fit5500 (NF), a β -galactosidase soluble preparation from *Bacillus licheniformis*, and Ha-Lactase 5200 (HL, a β -galactosidase soluble preparation from *Kluyveromyces lactis* were obtained from Chr. HANSEN (Denmark). GODO-YNL2 (GY) β -galactosidase, soluble preparation from *Kluyveromyces lactis*, was kindly provided by Danisco (Denmark). Acetonitrile (HPLC grade, $\geq 99.93\%$ purity), column SUPELCOSIL™ LC-NH2, (250 mm $\times$ 4.6 mm $\times$ 5 μ m), D-lactose monohydrate ($\geq 99.5\%$ purity), D(+) galactose ($\geq 99\%$ purity), D(+) glucose ($\geq 99.5\%$ purity) were purchased from Sigma-Aldrich (St. Louis, MO, USA), KOH ($\geq 85\%$, pellets) was purchased from EMSURE (Germany). Sweet whey permeate was donated by SC “Smiltenes piens”, and acid whey permeate from SC “Tukuma piens”. All reagents and solvents were of the highest available purity and used as purchased.

Determination of permeate content. Lactose, protein, fat and total solids contents were determined before solids concentration using a MilkoScan™ Mars, Foss Analytical SC (Denmark). Medium pH was determined with a pH-meter 720 pH meter (WTW, the Netherlands).

Solids concentration. Permeates with 20% (w·v⁻¹), 30% (w·v⁻¹) and 40% (w·v⁻¹) of solids concentration were ob-

tained, as previously described (Zolnere and Ciprovica, 2019).

Enzymatic hydrolysis of permeates. Lactose hydrolysis was performed as described previously (Zolnere and Ciprovica, 2019) with some modification. The hydrolysis of lactose in permeates was carried out by varying amounts of commercial enzymes (Table 1) added to 50 ml permeate. Permeates were kept in a thermostat (Mettler IN55, Germany) at temperature 42.5 °C for 4 h. The main properties of commercial enzymes used in the study are summarised in Table 2. pH was adjusted with 10% KOH solution prior to hydrolysis, for HL enzyme in the pH range of 6.5–6.6, for NF enzyme pH 5.4–5.6 and GY enzyme pH 7.5–7.6. Triplicate experiments were prepared for each type of permeate. After fermentation, samples were placed in a water bath at 90 °C for 5 min. Samples were transferred into 50 ml test tubes and placed in a freezer at –18 °C for further measurements.

The degree of lactose hydrolysis was calculated by the following equation:

$$H(\%) = \frac{L_0 - L_1}{L_0} \times 100$$

where: L_0 – initial lactose amount, g·L⁻¹; L_1 – the amount of lactose after hydrolysis, g·L⁻¹ (Vasileva *et al.*, 2016).

Table 1. Amount of added enzymes for experimental study (mean values $\pm$ sd (n = 3))

Enzyme prepare	Activity	Weight, mg*	Unit
Ha-Lactase 5200	5200 NLU·g ⁻¹	11.04 $\pm$ 0.91	57.41 $\pm$ 5.04 NLU
		52.48 $\pm$ 2.26	288.63 $\pm$ 12.41 NLU
		106.30 $\pm$ 2.35	584.64 $\pm$ 12.95 NLU
NOLA Fit5500	5500 BLU·g ⁻¹	10.83 $\pm$ 0.61	59.56 $\pm$ 2.26 BLU
		51.30 $\pm$ 2.00	282.15 $\pm$ 11.00 BLU
		104.16 $\pm$ 2.06	541.61 $\pm$ 11.37 BLU
GODO-YNL2	5000 NLU·g ⁻¹	11.37 $\pm$ 0.94	56.85 $\pm$ 5.15 NLU
		51.61 $\pm$ 1.76	283.83 $\pm$ 9.70 NLU
		107.27 $\pm$ 2.20	536.35 $\pm$ 12.12 NLU

* was calculated for 100 ml of whey permeates

Units of β -galactosidase activity are defined differently by each manufacturer. BLU, bifido lactase units; NLU; neutral lactase units.

Table 2. Summary of commercial enzymes main properties

Name	Dosage recommendation by producer	Manufacturer	Microorganism	Physical form	Protease. PU·ml ⁻¹	Enzymatic composition
GODO-YNL2	1 g·l ⁻¹	Danisco	<i>Kluyveromyces lactis</i>	Liquid	< 35	Lactase
Ha-Lactase 5200	500–4000 NLU·l ⁻¹	Chr. Hansen	<i>Kluyveromyces lactis</i>	Liquid	< 35	Lactase
NOLA™ Fit 5500	500–18000 BLU·l ⁻¹	Chr. Hansen	<i>Bacillus licheniformis</i>	Liquid	< 10	Lactase; Invertase (U·ml ⁻¹) <0.01; Arylsulfatase (A410·ml ⁻¹) <0.03; Glycoamylase (U·ml ⁻¹) <4; Lipase (LFU·ml ⁻¹) <0.07; Cellulase (U·ml ⁻¹) <3

Units of β -galactosidase activity are defined differently by each manufacturer. BLU, bifido lactase units; NLU, neutral lactase units.

High-performance liquid chromatography with refractive index detector (HPLC-RID). The amounts of lactose, glucose and galactose were determined as described by Zolnere and Ciprovica (2019). Samples were centrifuged for 5 min at 10 000 rpm. Then 1.5 ml of a sample was transferred into a sampler vial and sealed for HPLC analysis. HPLC (Prominence HPLC system, Shimadzu LC-20, Torrance, CA, USA) was used for sugar determination, refractive index detector RID-10A; column SUPELCOSILTM LC-NH2 (25 cm × 4.6 mm) 5 µm column; 35 °C temperature; gradient mobile phase acetonitrile: deionised water (80 : 20); volume of the injected sample: 10 µl; total analysis time 15 min; flow rate: 1.0 ml min⁻¹.

Statistical analysis. The results were expressed as mean ± standard deviation (SD) of three replicates for sugar measurements. Statistical analyses were carried out using two-factor ANOVA and Tukey tests. Differences were considered statistically significant when $p < 0.05$.

RESULTS

GY and HL enzymes contain only β-galactosidase, while the enzyme NF contains a very small quantity of enzymes other than β-galactosidase, suggesting that it can catalyse the hydrolysis of components other than lactose.

Prepared acid whey permeates with the initial lactose concentration $194.89 \pm 5.18 \text{ g} \cdot \text{l}^{-1}$, $273.65 \pm 16.99 \text{ g} \cdot \text{l}^{-1}$ and $391.17 \pm 11.81 \text{ g} \cdot \text{l}^{-1}$ were used for 4-hour hydrolysis. Higher hydrolysis rates for the NF enzyme (Fig. 1 A) was observed at acid whey permeate solids concentration 20% and 30% using 500 units: $98.89 \pm 8.14\%$ and $84.57 \pm 9.16\%$, respectively. Statistically, no significant ($p > 0.05$) difference was found between these results. With NF en-

zyme dose 250 units it was possible to hydrolyse more than half (50%) of the lactose in acid whey permeate (hydrolysis percentage range from $47.07 \pm 4.10\%$ to $76.05 \pm 3.47\%$). No significant ($p > 0.05$) difference was observed between permeate solids concentration 20% and 30%. Hydrolysis percentage of the HL enzyme (Fig. 1 B) doses at 20% and 30% permeate were not significantly different ($p > 0.05$). In the case of GY enzyme (Fig. 1 C) at doses 250 and 500 units for lactose hydrolysis, the hydrolysis percentage range was from 55.77 ± 1.36 to $79.80 \pm 3.31\%$.

Prepared sweet whey permeates with initial lactose concentration $200.72 \pm 8.25 \text{ g} \cdot \text{l}^{-1}$, $303.93 \pm 27.09 \text{ g} \cdot \text{l}^{-1}$ and $399.17 \pm 17.08 \text{ g} \cdot \text{l}^{-1}$ were used for 4-hour hydrolysis. Figure 2 illustrates similar behaviour for all enzymes. The percentage of lactose hydrolysis decreased with an increase of sweet whey permeate solids concentration. No significant differences were observed between lactose hydrolysis of permeate solids concentration 30% and 40% using 250 and 500 units of *Kluyveromyces lactis* enzymes (Fig. 2 B and C). The highest lactose hydrolysis for HL enzyme ranged from $77.67 \pm 1.49\%$ to $97.95 \pm 2.00\%$ and for GY enzyme from $50.55 \pm 0.96\%$ to $82.34 \pm 8.00\%$.

Tables 2 and 3 show the concentration of glucose and galactose formed during four hours of lactose hydrolysis in concentrated sweet and acid whey permeates using commercial enzymes. The monosaccharide concentration significantly differed between permeate concentrations. Addition of 50 units of enzymes to all concentrated permeates resulted in low monosaccharide formation, which was also reflected by insufficient enzyme activity. The HL enzyme showed the highest monosaccharide production capacity.

Comparing sugar profiles in Figure 3, the employed enzymes differed in formation of sugars other than lactose in

Fig. 1. Comparison of lactose hydrolysis by 3 commercial enzymes at different concentrations at various acid whey permeate solids concentration (20%, 30% and 40% w.v⁻¹). Panel A shows the hydrolysis results of enzyme NOLA Fit5500. Panel B shows the hydrolysis results of enzyme Ha-Lactase 5200. Panel C shows the hydrolysis results of enzyme GODO-YNL2.

* data on hydrolysis of lactose using 500 units of enzyme NF. HL and GY was taken from Zolnere & Ciprovica (2019). Means followed by the same letter do not differ significantly by Tukey's test ($p > 0.05$).

Fig. 2. Comparison of lactose hydrolysis by 3 commercial enzymes at different concentrations at various sweet whey permeate solids concentration (20%, 30% and 40% w.v⁻¹). Panel A shows the hydrolysis results of enzyme NOLA Fit500. Panel B shows the hydrolysis results of enzyme Ha-Lactase 5200. Panel C shows the hydrolysis results of enzyme GODO-YNL2.

* obtained data on hydrolysis of lactose using 500 units of enzymes was taken from Zolnere & Ciprovica (2019). Means followed by the same letter do not differ significantly by Tukey's test ($p > 0.05$).

Table 3. Characteristics of acid and sweet whey

Permeate	Fat, %	Proteins, %	Lactose, %	Total solids, %	pH
Sweet whey	<0.1	0.2 ± 0.1	3.8 ± 0.1	4.6 ± 0.1	6.1 ± 0.1
Acid whey	<0.1	0.5 ± 0.1	4.2 ± 0.2	5.2 ± 0.2	4.6 ± 0.1

acid whey permeates. Using 50 units of enzymes the other sugar yield ranged from 4.25 to 31.66% and 2.70 to 12.62% in acid and sweet whey permeates, respectively. The formation of other sugars using 250 units of the enzyme was in

the range from 2.35 to 30.30% and from 1.91 to 22.21% in acid and sweet whey permeate solutions, respectively.

DISCUSSION

One of the important factors that can significantly impact the hydrolysis reaction is the added enzyme amount, which determines the conditions which need to be set up for the reaction and also to the final sugar profile. Description of other enzymes present in the NF enzyme preparation are as

Fig. 3. Lactose conversion and galacto-oligosaccharides formation during hydrolysis of lactose in acid and sweet whey permeate solutions. Sugar profile using 50 units (A) and 250 units (C) of commercial enzymes in sweet whey permeate solutions. Sugar profile using 50 units (B) and 250 units (D) of commercial enzymes in acid whey permeate solutions.

follows: invertase (β -fructofuranosidase (EC.3.2.1.26)) hydrolyses sucrose into glucose and fructose (Soares *et al.*, 2019); arylsulfatase (E.C.3.1.6.1) hydrolyses arylsulfate esters into aryl- compounds and inorganic sulphates (Wang *et al.*, 2016); glucoamylase (γ -amylase (EC 3.2.1.3)) hydrolyses α -1-4, α -1-6 glycosidic bonds in starch and malto-oligosaccharides (Meng *et al.*, 2018); lipases (triacylglycerol hydrolases (E.C. 3.1.1.3)) hydrolyse many reactions such as hydrolysis or synthesis of esters, esterifications, aminations, alcoholysis, and others (Rios *et al.*, 2018). Cellulase (endoglucanases (EnG) (EC 3.2.1.4)), exoglucanases (ExG) (EC 3.2.1.94) and β -glycosidases (BG) (EC 3.2.1.21) hydrolyse 1,4- β -glucosidic bonds of cellulose into smaller subunits (Sankarraj and Nallathambi, 2018). Whey passing through an ultrafiltration membrane where protein is removed, but smaller molecules such as lactose and salts pass through becoming the basis of whey permeate (Barile *et al.*, 2009). In our study the concentration of main components of whey permeates were determined (Table 3). The difference of lactose concentration in permeates may be affected by the membranes used for ultrafiltration. The characteristics of whey permeate is affected by membrane pore size, equipment options and processing conditions. Moreover, each permeate was obtained from separate dairy facilities, which use different techniques and processing procedures for product production. It clearly indicates a high possibility that use of NF enzyme for lactose hydrolysis of whey permeate can result in hydrolysis of components (lipid, protein) other than lactose. These reactions would catalyse the formation of new substances, which would influence β -galactosidase velocity and lactose hydrolysis efficiency.

One specific reaction conditions will not be suitable for all β -galactosidase enzymes. For instance, medium pH values between 2.5 and 5.4 are optimal for β -galactosidase enzymes obtained from bacteria and are mainly used for acid whey lactose hydrolysis. In turn, medium pH values between 6.0 and 7.0 are optimal for β -galactosidase obtained from yeasts, which are used for milk and sweet whey lactose hydrolysis (Saqib *et al.*, 2017). It should be noticed that substrate adjustment to enzyme optimal pH needs to be used for a solvent that serves as an activator for a particular enzyme and influences its velocity. Zolnere and Ciprovica (2019) reported that the major monovalent ion activator for *Kluyveromyces lactis* β -galactosidase is K^+ ion, but for *Bacillus licheniformis* β -galactosidase K^+ and Na^+ .

Comparison of the commercial enzyme capacity to hydrolyse lactose revealed that all enzyme units have higher lactose hydrolysis potential at permeate solids concentrations of 20%, 30% and 40% ($w \cdot v^{-1}$) using *Kluyveromyces lactis* enzymes. This indicates that the permeate composition and the pH adjustment solution activated the enzyme of this particular species well. Rodriguez-Colinas *et al.* (2014) reported that lactose conversion in skimmed milk using *Kluyveromyces lactis* β -galactosidase (commercial preparation Lactozym pure 6500 L) was obtained at a significantly high hydrolysis percentage (95%) than for *Aspergillus oryzae* β -galactosidase (commercial preparation Lactase F),

which showed 43% and *Bacillus circulans* β -galactosidase (commercial preparation Biolactase NTL-CONC) — 50%. Also, *Bacillus licheniformis* β -galactosidase lactose hydrolysis results were lower. This suggests that the process conditions may not be appropriate and need to be improved.

The experimental results were compared taking into account the final sugar profile and initial solids concentration that showed that the highest lactose hydrolysis: solids concentration 20% ($w \cdot v^{-1}$) and at enzyme 250 and 500 units for both permeates. As an exception would be HL, which showed similar results using 250 units of the enzyme in all permeate solids concentrations. According to Martínez-Villaluenga *et al.* (2008), rapid lactose hydrolysis occurred when initial lactose concentration was 150 and 250 $mg \cdot mL^{-1}$ using 3 $U \cdot mL^{-1}$ of Lactozym 3000 L HP G (*Kluyveromyces lactis*) enzyme. Our results showed that using 20% ($w \cdot v^{-1}$) acid whey permeate as a substrate, enzymes can produce more other sugars than using sweet whey permeate. This can be explained by the addition of KOH solution for substrate pH adjustment. Our finding is also supported by the results of Rajakala & Karthigai Selvi (2006), who reported that higher lactose hydrolysis (86,6%) was obtained using KOH for whey pH control. Ion impact on enzyme activity is based on the ionic radius, which is tighter for Na^+ than for K^+ , and this also affects the enzyme structure. The authors recommended that KOH is more suitable to use for whey pH adjustment than NaOH, which can inhibit β -galactosidase enzyme activity (Rajakala and Karthigai Selvi, 2006). It is important to highlight that, based on European Regulation No. 231/2012 (Anonymous, 2012), potassium hydroxide is a food additive (E525) that is safe to use it for lactose hydrolysis.

Hydrolysis results (Tables 4 and 5) showed that using 50 unit of enzymes, in many cases the amounts of glucose and galactose were more or less equal and the total amount of monosaccharides was quite low. This suggests that on an industrial scale, for production of glucose-galactose syrup for a specific permeate concentration, the concentration of enzyme needs to be increased above 50 enzyme units. Use of 250 and 500 units of enzymes resulted in high concentration of glucose and less concentration of galactose, which indicates a transgalactosylation reaction. During hydrolysis, the lactose concentration decreases and equimolar glucose and galactose concentrations develop. When the concentration of monosaccharides reaches a certain level, the production of oligosaccharides or transgalactosylation is initiated (Das *et al.*, 2011). Other sugar molecules may be the acceptor, and then the galactose is transferred to another carbohydrate, and oligosaccharides with a higher degree of polymerisation are obtained (Otieno, 2010). This explains the occurrence of galacto-oligosaccharides during hydrolysis in our study. It should be highlighted that the high glucose concentration in the medium could be considered as an inhibitor of enzyme activity, as described in Demirhan *et al.*, 2008 and Mano *et al.*, 2018 reports. The amount of galacto-oligosaccharides depends on substrate type, its solids concentration and enzyme amount.

Table 4. Monosaccharides composition using several sweet whey solids and enzyme concentrations

Enzyme	Solids concentration, %	Glucose, g·l ⁻¹			Galactose, g·l ⁻¹		
		50 units	250 units	500 units*	50 units	250 units	500 units*
NF	20	17.22 ± 3.39	57.55 ± 2.15	90.71 ± 18.52	14.78 ± 1.44	17.91 ± 1.85	37.45 ± 4.55
	30	10.73 ± 1.89	30.36 ± 0.22	85.47 ± 8.07	11.06 ± 0.55	35.17 ± 3.43	28.96 ± 15.01
	40	6.48 ± 1.58	22.40 ± 2.25	70.27 ± 8.00	12.57 ± 1.70	15.38 ± 0.32	23.61 ± 6.37
HL	20	42.67 ± 3.45	78.98 ± 0.71	116.41 ± 16.97	25.58 ± 0.73	25.08 ± 1.59	37.87 ± 16.90
	30	25.36 ± 5.32	82.70 ± 6.81	106.54 ± 22.64	32.92 ± 2.02	20.81 ± 2.23	35.49 ± 15.70
	40	20.18 ± 0.53	87.03 ± 1.98	122.89 ± 7.00	28.78 ± 0.53	22.82 ± 2.40	31.07 ± 10.00
GY	20	38.11 ± 1.41	66.06 ± 2.66	67.00 ± 3.56	20.28 ± 1.13	14.58 ± 0.86	20.47 ± 3.37
	30	12.98 ± 3.15	85.74 ± 7.55	59.14 ± 5.60	13.40 ± 9.05	23.46 ± 4.08	21.74 ± 13.44
	40	7.05 ± 0.95	45.56 ± 9.20	37.46 ± 3.56	12.44 ± 0.33	17.96 ± 4.08	37.46 ± 9.00

* obtained data on hydrolysis of lactose using 500 units of enzymes was taken from Zolnere and Ciprovica (2019)

Table 5. Monosaccharides composition at certain acid whey solids and enzyme concentrations

Enzyme	Solids concentration, %	Glucose, g·l ⁻¹			Galactose, g·l ⁻¹		
		50 units	250 units	500 units*	50 units	250 units	500 units*
NF	20	14.89 ± 2.47	53.40 ± 0.84	65.39 ± 9.16	19.04 ± 10.87	25.74 ± 1.32	70.09 ± 15.10
	30	21.06 ± 4.17	61.57 ± 4.48	53.03 ± 16.03	13.57 ± 1.43	26.87 ± 2.11	81.40 ± 4.46
	40	10.89 ± 0.97	108.96 ± 9.01	73.72 ± 9.16	14.80 ± 1.29	74.45 ± 6.48	35.20 ± 21.74
HL	20	33.90 ± 4.74	64.40 ± 1.51	60.56 ± 4.88	21.61 ± 0.53	25.74 ± 0.96	22.02 ± 3.25
	30	23.20 ± 7.77	69.67 ± 3.77	64.81 ± 6.54	16.57 ± 1.20	34.34 ± 1.57	27.25 ± 10.25
	40	26.93 ± 2.41	161.26 ± 9.37	66.61 ± 4.88	34.66 ± 3.10	72.19 ± 6.66	54.07 ± 7.00
GY	20	18.80 ± 0.24	42.04 ± 1.09	51.32 ± 7.09	11.44 ± 0.51	20.22 ± 1.68	27.49 ± 0.35
	30	21.15 ± 3.77	68.27 ± 9.42	56.50 ± 0.04	22.34 ± 0.04	16.42 ± 1.03	26.40 ± 8.00
	40	16.67 ± 1.73	54.00 ± 5.30	45.15 ± 7.07	26.97 ± 3.25	33.75 ± 3.29	28.43 ± 10.00

* obtained data on hydrolysis of lactose using 500 units of enzymes was taken from Zolnere and Ciprovica (2019)

The enzyme concentration is one of the critical factors to be taken into account in enzymatic hydrolysis processes, both in terms of yield and activity. It should also be considered in choice of the substrate for hydrolysis. Data from this study showed wider and more specific information of effects of both permeate concentration and as well as enzyme amount on lactose hydrolysis and glucose and galactose outcome. Sweet and acid whey permeates are suitable substrates for glucose-galactose syrup production. Comparing the two whey permeates in lactose hydrolysis, a higher percentage of hydrolysis was obtained using acid whey. The most suitable lactose hydrolysis concentration was 20% of total solids and 250 units of enzymes. Whey permeate hydrolysis into glucose — galactose syrup provides manufacturing opportunities to use whey as a valuable raw material and perspectives for whey vaporisation.

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LAKTOZES HIDROLĪZES APSTĀKĻU OPTIMIZĀCIJA DAŽĀDAS SŪKALU SAUSNAS UN β -GALAKTOZIDĀZES KONCENTRĀCIJAS IETEKMĒ

Pētījuma mērķis bija izvērtēt, kādos apstākļos β -galaktozidāze (NOLA Fit5500 un Ha-Lactase 5200, Chr. HANSEN (Dānija) un GODO-YNL2, Danisco (Dānija)) spēj efektīvi hidrolizēt laktozi glikozē un galaktozē. Laktoze, glikoze un galaktoze noteikta ar HPLC-RID. Hidrolīze veikta optimālā enzīma temperatūrā 42,5 °C 4 stundas. Hidrolīzes procesa laikā vides pH tika regulēts, izmantojot 10% KOH. Eksperimenta rezultāti salīdzināti pēc iegūto cukuru profila un noskaidrots, ka augstākā laktozes hidrolīzes pakāpe tika sasniegta substrātiem ar sausnas saturu 20% (w·v⁻¹), pievienojot 250 un 500 enzīma vienības. Izmantojot 50 enzīma vienības, tika iegūts praktiski vienāds glikozes un galaktozes saturs, lai gan kopējais monosaharīdu saturs bija salīdzinoši zems. Salīdzinot siera un biezpiena sūkalu fermentācijas iespējas ar β -galaktozidāzi, augstāku laktozes hidrolīzes pakāpi var sasniegt, izmantojot tieši biezpiena sūkalas.