ORIGINAL ARTICLE

Factors affecting lactose quantity in raw milk

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Abstract

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The purpose of this study was to characterize factors affecting lactose quantities in raw cow's milk. This study combined the survey design with laboratory analysis. Selected farm members of Nong Poh Dairy Cooperatives, from Ban Pong and Photharam Districts, Ratchaburi Province, were sampled. From the selected farms, data collected included lactose quantities in the raw milk and dairy farming information. The raw milk of selected farms was sampled at the delivery site of Nong Poh dairy cooperatives in the morning during December 2003 till February 2004. Lactose in the raw milk was then quantified by the Fourier Transform Infrared Analysis (FTIR) using the MilkoScan FT6000 at the Department of Livestock Development. The farm owners or managers of selected farms were in-depth interviewed on dairy farming information including cowsí health and cows' diet. The data revealed that all cows from the selected farms were fed with concentrate diet purchased from Nong Poh Dairy Cooperatives and grass as high fiber diets. Sample of eighteen farms also fed their cows with one of supplements: corn stem, soybean meal, or rice straw. All cows from these farms were Holstein-Friesian Hybrid. As supplemented high fiber diets, corn stem significantly increased the lactose quantities over soybean meal and rice straw (planned comparison, p-value = 0.044). The study concluded that some high fiber diets, specifically corn stem, significantly contributed to the lactose quantities in raw milk.

Key words : dairy farm, lactose, milk, supplemented diet

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ปัจจัยที่มีผลต่อปริมาณแลคโตสในน้ำนมดิบ

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การวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาปัจจัยที่มีผลต่อปริมาณแลคโตสในน้ำนมดิบ โดยการสำรวจข้อมูลฟาร์มจากการเลือกตัวอย่างฟาร์มโคนมซึ่งเป็นสมาชิกสหกรณ์โคนมหนองโพ ในตำบลบ้านโป่ง อำเภอบ้านโป่ง และตำบลโพธาราม อำเภอโพธาราม จังหวัดราชบุรี ร่วมกับการวิเคราะห์ข้อมูลน้ำนมดิบในห้องปฏิบัติการ เพื่อรวบรวมข้อมูลการทำฟาร์มและปริมาณแลคโตสในน้ำนมดิบ การเก็บข้อมูลน้ำนมดิบทำในช่วงเดือนธันวาคม 2546 ถึงเดือนกุมภาพันธ์ 2547 ตัวอย่างน้ำนมดิบได้จากนมที่เกษตรกรมาส่งที่ศูนย์รับนมของสหกรณ์ฯในช่วงเช้า การวิเคราะห์หาปริมาณแลคโตสใช้วิธี Fourier Transform Infrared Analysis (FTIR) ด้วยเครื่องมือ MilkoScan FT6000 ที่กรมปศุสัตว์

จากการสัมภาษณ์เจ้าของฟาร์มหรือผู้จัดการเกี่ยวกับสุขภาพของโคนมและอาหารที่ใช้เลี้ยงโคนมทั้งอาหารข้นและอาหารหยาบ พบว่า พันธุ์โคเป็นลูกผสมโฮลสไตน์-ฟรีเซียน มีการใช้อาหารข้นของสหกรณ์โคนมหนองโพ และหญ้าเป็นอาหารหยาบ นอกจากนี้ พบ 18 ฟาร์ที่มีการผสมฟางข้าว ต้นข้าวโพด หรือกากถั่วเหลืองอย่างใดอย่างหนึ่งเพิ่มเป็นอาหารเสริม จากการวิเคราะห์ข้อมูลโดยใช้ planned comparison พบว่าการเสริมต้นข้าวโพดในอาหารหยาบมีผลทำให้ปริมาณแลคโตสในน้ำนมดิบเพิ่มขึ้นอย่างมีนัยสำคัญ (p-value = 0.044) มากกว่าการใช้แต่ฟางข้าวและกากถั่วเหลือง การศึกษานี้สรุปได้ว่าชนิดของอาหารที่ใช้โดยเฉพาะต้นข้าวโพด มีผลต่อปริมาณแลคโตสในน้ำนมดิบ

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Lactose, a disaccharide sugar made up of a glucose and a galactose molecule, has been widely used for various purposes in pharmaceutical and food industries. Being physically and chemically inert, lactose thus becomes a good supplement in many drug formulations. Anhydrous lactose may be employed as an excipient, filler, diluent, diuretic drug, and a bulking agent in a wide variety of pharmaceutical preparations (Ferrari *et al.*, 2004 and Martindale, 1996). Moreover, it is intensively used as a nutrient and multifunctional ingredient in infant formulas, geriatric, dietetic, and health foods (American Academy of Pediatrics, 1985).

The main source of lactose used in industry is from milk. The method for separating lactose from milk has been well established. Briefly, lactose is isolated from whey, which is available after the production of cheese. The basic principle of lactose production is the removal of water from whey by evaporation to increase the concentration of lactose. Then the condensed whey is gradually cooled down to allow crystallization and separation of lactose (Kosikowski, 1979 and Rossano *et al.*, 2001).

As a carbohydrate source in milk, lactose is by weight the most abundant of the milk solids. The previous study showed that lactose concentration in raw milk was varied depending on different locations (Kittivachra *et al.*, 2003). We hypothesized that lactose concentration could depend on type or quantity of diet uptake by cow. In an attempt to identify factors that control lactose level, we combined the survey design with the laboratory analysis.

Developing pharmaceutical and food industries require increasing demand of imported lactose causing a negative shift on the Thai economy. Potential local production of lactose could serve as a solution to alleviate this economic burden. Starting from the national policy to extensively develop and promote dairy farming in Thailand for more than 40 years, the high level of dairy production has resulted in the excess of raw

milk produce within the country (Committee on Agriculture and Co-operatives, 2003). The previous study pointed toward a promising opportunity to use milk as a novel source for lactose production (Kittivachra *et al.*, 2006).

In summary, this research is to determine the effect of supplemented feed (corn stem, soybean meal, or rice straw) on lactose concentration in milk that might benefit the use of milk as a new source of lactose. In addition separating lactose from milk might be the great opportunity for local pharmaceutical and food industries.

Materials and Methods

All of the experiments in this study using the combination of the survey design with the laboratory analysis. The farm owners or managers were in-depth interviewed on dairy farming information including cow's health, and type and amount of cow's diet. This information was used for dividing cows into the study groups depending on the cow's diet. The dairy farms and their raw milk were selected and sampled, followed by the nutrient analysis as detailed below.

1. Dairy farm selection criteria

1. The dairy farms were located largely in the same area and sent their raw milk to the same delivery site. For convenience, Ban Pong and Photharam Districts, Ratchaburi Province were then targeted.

2. The cows were be Holstein-Friesian crossbred (90% Holstein-Friesian) with the age of 5.22±1.53 years .

3. All cows were feed with the same standard concentrate diet purchased from Nong Pho Dairy Cooperatives (Ratchaburi, Thailand) and grass as high fiber diet with supplemented feed such as corn stem, soybean meal, and rice straw.

The nutritional values of standard concentrate diet were protein 16%, fat 3%, sodium chloride 0.8% and crude fiber not more than 14%.On the average, each cow was fed 5.62 kg./ day of concentrate diets and 32.35 kg./day of high fiber diets.

4. The cows were usually milked twice daily, in the morning and in the afternoon.

2. Dairy farms and milk samples

Eighteen farms that met the selection criteria and were willing to participate in the study were recruited. All farm were members of Nong Pho Dairy Cooperatives. They consisted of nine small farms, seven medium size farms and two large farms with average of 12, 46, and 254 dairy cows of which about 48 % were lactating cows.

The raw milk from each group of cows was sampled in the morning for 4-6 different periods during December 2003 till February 2004, which was the period of winter season with temperature ranging from 15.9^{o}C to 37.0^{o}C (Meterological Development Bureau, 2003 and 2004). All samples were kept in an ice-cooled box and sent to Department of Livestock Development for laboratory analysis.

3. Lactose and protein analysis

Fresh milk samples were analyzed for lactose, protein and total solid by the Fourier Transform Infrared Analysis (FTIR) using the MilkoScan FT6000 (Foss Electric, Hillerd, Denmark) at National Institute of Animal Health (NIAH), Department of Livestock Development. Milk samples for FTIR analysis were kept at 2-5 ^{o}C for less than 48 h. The milk samples of 8.5 mL (5.0-12.0 mL in range) were heated in a water bath at 40-42^{o}C and were then tested by the MilkoScan for 30 to 45 s.

Statistical Analysis

The background data were descriptively presented using mean±S.D. The concentration of milk components were compared across the various locations by one-way analysis of variance (one-way ANOVA), followed by Tukey multiple-comparison analysis. The lactose, protein and total solid concentration in milk were compared across the different feeding groups by priori contrast ANOVA. Differences of the means were considered to be significant when p-value < 0.05.

Results

The results of the nutrient analysis from our previous study showed that raw milk from different locations had different protein and lactose contents (Kittivachra *et al.*, 2003). In particular, lactose seems to be the most variable nutrient affected by different locations (Table 1).

Since different locations affected the content of lactose concentration, we further investigated the effect of type of feed on lactose concentration in milk. The cows from the selected farms were fed with two types of diet. The standard concentrated diets and high fiber diets with supplemented feeds. On the average, each cow was fed 5.62 kg/cow/day of concentrate diets and 32.35 kg/cow/day of high fiber diets. Information of supplemented foods of these farms were then used to divided cows into 3 categories which were 1) fed with corn stem (n = 6), 2) fed with soybean meal (n = 5), and 3) fed with rice straw (n = 7). Then the data were analyzed using priori contrast ANOVA or planned comparison of nutrients quantity among cows fed with three different types of supplement. Three planned comparisons were conducted for each nutrient. Each analysis compared between cows fed with one type of supplements against the other two. Table 2 shows the descriptive statistics of nutrient quantity across 3 different supplements. The results in Table 3 revealed that milk from cows

Table 1. Comparison of nutrient contents among various locations using one-way ANOVA. (* indicates significant with p < 0.05)

Nutrients (%w/w)	Location of dairy farms									P value
	Ratchaburi (n=40)			Petchaburi (n=21)			Saraburi (n-38)			
	Mean	SD	%CV	Mean	SD	%CV	Mean	SD	%CV	
Protein	3.24	0.21	6.48	3.1	0.25	8.07	3.19	0.56	17.56	0.078
Lactose	4.68 [a]	0.10	2.14	4.63	0.09	1.94	4.62 [a]	0.09	1.94	0.023*

Note: a denotes the pairwise significant difference

Table 2. Descriptive statistics of nutrient contents in milk from cow fed with different supplements

Nutrients (%w/w)	Supplements	N	Mean	Standard deviation	%CV
Lactose	Corn stem	6	4.7469	.07426	1.564
	Soybean meal	5	4.6628	.12383	2.656
	Rice straw	7	4.6571	.08762	1.881
	Total	18	4.6886	.09872	2.106
Protein	Corn stem	6	3.1489	.20341	6.460
	Soybean meal	5	3.4204	.18640	5.450
	Rice straw	7	3.1570	.21922	6.944
	Total	18	3.2274	.22908	7.098
Total solid	Corn stem	6	12.5933	.44473	3.531
	Soybean meal	5	13.1280	.34172	2.603
	Rice straw	7	12.6071	.43611	3.459
	Total	18	12.7472	.46028	3.611

Table 3. Comparison of nutrient contents in milk from cow fed with different supplements (* indicates significant with p < 0.05 using priori contrast ANOVA)

Nutrients (%w/w)	Contrast	Value of Contrast	Std. Error	t	df	Sig. (1-tailed)
Protein	Corn stem vs soybean meal and rice straw	-.1398	.10330	-1.353	15	.098
	Soybean meal vs corn stem and rice straw	.2675	.10829	2.470	15	*.013
	Rice straw vs corn stem and soybean meal	-.1276	.09958	-1.282	15	.110
Lactose	Corn stem vs soybean meal and rice straw	.0870	.04765	1.825	15	*.044
	Soybean meal vs corn stem and rice straw	-.0392	.04996	-.785	15	.223
	Rice straw vs corn stem and soybean meal	-.0478	.04594	-1.040	15	.158
Total solid	Corn stem vs soybean meal and rice straw	-.2742	.20904	-1.312	15	.105
	Soybean meal vs corn stem and rice straw	.5278	.21915	2.408	15	*.015
	Rice straw vs corn stem and soybean meal	-.2535	.20151	-1.258	15	.114

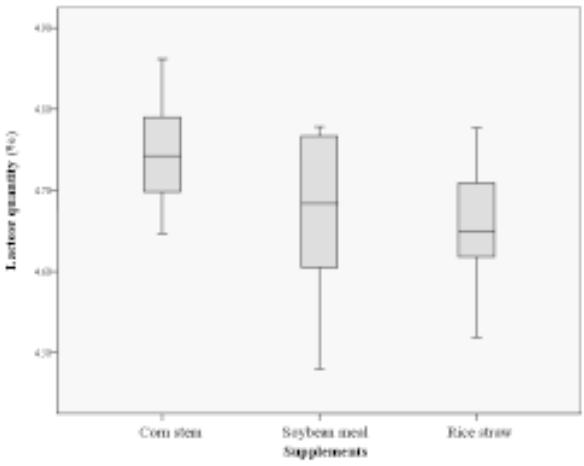

Figure 1. Comparison of lactose content in milk from cow fed with different supplements

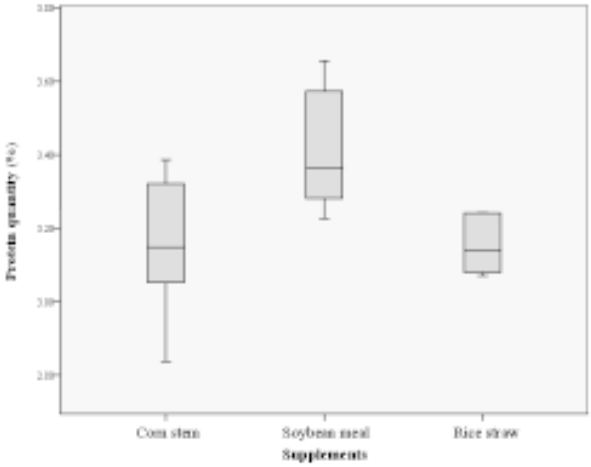

Figure 2. Comparison of protein content in milk from cows fed with different supplements

fed with corn contained significantly higher quantity of lactose than those fed with rice straw or soybean meal (p-value = 0.044).

Since protein has been considered as an important ingredients defining quality of various food including milk, we thus further investigated the effect of supplemented feed on protein concentration in milk. The data of cow's diets were recorded as previously described. The analysis illustrated that the milk from cows fed with soybean meal was significantly increased in protein concentration (p-value = 0.013).

Discussion and Conclusion

The results from nutrient analysis of raw milk samples in this study indicated that the nutrition of cows affected the lactose content in the milk. Cows fed with corn stem and other supplements, i.e. soybean meal and rice straw had shown significant difference of lactose quantity. In more detail, corn stem which contain 30.5-36.2% dry weight of crude fiber and 6.5-9.1 %dry weight of crude protein (Department of Livestock Development, 2005) can be used as a precursor for glucose

production and thus increase the lactose synthesis. The principal precursor of lactose is blood glucose. In the cow 60-70% of the blood glucose taken up is utilized for lactose synthesis in the alveolar epithelial cell (Tucker, 2006). Certain micro-organisms in the cow's rumen produce volatile fatty acids (VFA) such as acetate, proprionate and butyrate as end products of fermentation of cellulose and other sugars. Proprionate is almost completely removed from portal blood by the liver (Bowen,1996; Wattiaux and Howard,2006). Within the liver, proprionate serves as a major substrate for gluconeogenesis, and accounts for 45-60% of glucose formed in ruminants. Gluconeogenesis from non-sugars accounts for 40-55% of glucose; takes place outside mammary gland and involves breakdown of protein (Tucker,2006).

The availability of glucogenous compounds in cows is an important feed nutrition factor. Milk is isotonic with blood. A reduction in glucose availability is a limiting factor in milk production. If glucose is decreased then lactose, water secretion into milk and milk volume are decreased. Thus, there is high correlation between milk yield and glucose uptake from blood.

Together with previous findings, not only the nutrition of cow affects the concentration of nutrients in the milk, but also seasonal factors, e.g. different times of year, appeared to influence the level of protein and lactose in the milk (Kittivachra *et al.*, 2003 and Kittivachra *et al.*, 2006). Good understanding of how these factors affect the quality and quantity of milk could benefit the production of milk products and also facilitate the production of by-products from milk as well.

In summary, the knowledge derived from this research provides the potential principle for farming to improve the quality of milk produced particularly the increase in lactose and protein contents. This high lactose or high protein milk is, through this study, proposed as a prospective alternative for lactose or protein production which at the same time increases the value of the raw milk. Several industries, for instance cheese, butter, and lactose production, could then benefit both knowledgewise and economicwise.

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