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Effects of different starch sources in concentrates on meat characteristics, nutrient composition, and collagen solubility of dairy steers

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Abstract The influences of three different starch sources in concentrates - ground corn (CO), ground cassava (CA), and pineapple stem starch (PI) formulated as a 40% in concentrate - on meat quality, texture profile, nutrient composition, and collagen solubility of the *Longissimus thoracis* (LT) of dairy steers were investigated. Meat quality and texture profile did not differ significantly between treatments ($P>0.05$). Nutrient composition did not differ between treatments except that ash content of PI was higher than the other treatments ($P<0.05$). Starch sources had no effect on collagen content and solubility in LT muscle. Based on the results of this study, pineapple stem starch can be used as an alternative energy source in concentrates without negative effects on meat characteristics.

Keywords: Starch source, Meat characteristics, Texture profile, Collagen solubility

Introduction

Most of the beef cattle raised in Thailand have the characteristics of *Bos indicus* (Zebu) (Wangkumhang *et al*., 2015). The quantity of beef cattle is insufficient to meet the demand because the population is growing rapidly and economic expansion and prosperity are contributing to an increase in the demand for food for domestic consumption (Tassapong, 2014). Therefore, the production of beef from beef cattle breeds is not sufficient to meet consumer demand. Castrated male fattened dairy cattles or dairy steers are a source of

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beef production that can significantly increase the supply for meat consumption.

Holstein Friesian is a dairy breed that originated in Friesland and North Holland. They are large dairy cattle with a distinctive black and white spotted pattern (Sheffer, 2008). Female dairy calves are raised for milk production (Tieoyong, 2018). Male dairy cattle are generally less suitable for beef production due to their less efficient feed conversion. The percentage of finishing carcass is 6-8 percentage points lower in the Holstein breed than in beef breeds. In addition, Holstein steer carcasses (at constant weight) have less marbling, total fat, and backfat, but more bone and protein compared to beef breeds (Grant *et al*., 1993). To meet current market demand, improving the quality and quantity of beef is recommended. To improve these, superior crosses between foreign breeds and indigenous species are used and nutritional management is also improved. In addition, the effective implementation of the fattened male dairy cattle system in beef production can increase beef production and farmers' income and create opportunities for value addition in dairy farming (Khenjan *et al*., 2015; Li *et al*., 2014).

Pineapple (*Ananas comosus*) is one of the most popular tropical fruits (Wu *et al*., 2021). The main product from pineapple cultivation is the pineapple fruit, which accounts for 45 percent, while the pineapple stems remaining in the field account for about 16.12 percent and the leaves account for about 38.78 percent (Sawanon, 2018). Sruamsiri, (2007) mentioned that farmers use pineapple waste as roughage for cattle because it is palatable. The high moisture content and soluble carbohydrates make them a good source of roughage for cattle, however, they rot quickly. Therefore, farmers usually accept drying and ensiling as preservation methods. In addition, cattle prefer fermented pineapple waste to fresh waste, which has a high acid content. Kyawt *et al*. (2020) reported that feeding Myanmar local cattle with pineapple waste silage as a roughage source at 25% of the diet improved nutrient intake, energy balance, and body weight gain. Similarly, Hattakum *et al*. (2019) reported that fed cattle with pineapple stem by-products they had similar growth performance, rumen fermentation, and carcass and meat quality but had lower feed cost compared to feed them with two popular roughages - Napier grass and whole corn.

The enzyme bromelain is a proteolytic enzyme that can be used in certain cosmetics, dietary supplements, and also as a phytomedicinal agent (Ketnawa, *et al*., 2012; Manzoor *et al*., 2016). In the past, the pineapple stem was left to be dried and burn before replanting. More recently, the pineapple stem has been used to extract the enzyme bromelain, with starch as a by-product (pineapple stem starch) (Ketnawa *et al.*, 2012). Khongpradit *et al*. (2020) reported that pineapple stem starch can be used as an alternative starch source that significantly improves rumen fermentation and growth performance of dairy steers compared to ground corn and ground cassava. Khongpradit *et al*. (in press) also reported that pineapple stem starch could be a cost-effective source of energy in concentrates for beef cattle without compromising meat quality. However, there is limited information on the effects of pineapple stem starch on meat characteristics. Therefore, the objective of this study was to determine the effects of pineapple stem starch as a source of starch in concentrates on meat quality, texture profile, nutrient composition, and collagen solubility of finishing dairy steers comparing with the corn and cassava starch sources.

Materials and methods

Animal ethics

The experimental procedure was approved by the Animal Usage and Ethics Committee of Kasetsart University, Thailand (ACKU62-AGK-007).

Experimental cattle and Muscle collection

Thirty-six Holstein Friesian steers, 22 months of age and weighing 453 ± 35.3 kg, were divided into three groups (12 steers/group) and randomly fed three different fattening diets: ground corn (CO), ground cassava (CA), or pineapple stem starch (PI) formulated as a 40% starch in concentrate. Napier grass silage and rice straw were used as roughage sources during the fattening period. After a fattening period of 206 days, the animals were slaughtered and the carcasses were stored at about 1 ℃ for 14 days. After 14 days aging, the *Longissimus thoracis* (LT) was taken from the right side of each carcass. The samples were trimmed of all visible fat and cut into two 3 cm thick subsamples. The first subsample had its pH and colour measured before being vacuum packed and stored at -20 ℃ until the next shear force measurement. The second subsample was vacuum packed and stored at -20 ℃ until the subsequent proximate analysis and measurement of collagen content.

pH measurement

Muscle pH of muscle sample (LT) from the right side of each carcass were recorded at 14 d postmortem by using a portable pH meter with a spear tip glass probe(SG2 - ELK Seven Go™, Mettler Toledo International, Shanghai, China).

Color measurement

The meat color values of muscle sample (LT) after a 30 minutes of bloom time were measured using a handheld colorimeter (MiniScan®EZ 45/0 LAV, Hunter Associates Laboratory Inc., Virginia, USA).

Water loss, Shear force, and Texture profile measurement

Muscle samples were weighted and thawed at 4 ℃ and then weighed again. The weight had undergone thawing were expressed as percentages of thawing loss. After thawing, muscle samples were boiled in a water bath (One14, Memmert, Buchenbach, Germany) for approximately 20 min until an internal temperature of 70 ℃ was reached. The cooked samples were cooled under running tap water for 30 minutes before weighing. The weight loss after cooking was calculated and evaluated as percentage cooking loss. The cooked samples were cut into 1 cm thick slices with 8 pieces cut parallel to the fiber orientation of the cooked sample. The shear force value was measured using a texture analyzer (Model EZ-SX, Shimadzu, Kyoto, Japan). For texture profile analysis (TPA), the cooked sample was cut into at least four 15 mm cubes. A texture analyzer with a 36 mm diameter cylindrical probe was used to determine TPA (Model EZ-SX, Shimadzu, Kyoto, Japan).

Collagen content measurement

Total, insoluble and soluble collagens were determined according to the method described by Hill (1966). The 4 g minced meat sample was added to 3 mL of ¼-strength Ringer's solution and homogenized using a polytron (T20, Ika, Switzerland). The probe was then rinsed with 2 mL of ¼ strength Ringer's solution. The homogenized sample was placed in a water bath at 77^{o}C for 60 minutes and then centrifuged at 2,500 x g for 10 minutes. The supernatant solutions were hydrolyzed in 12 N HCl and the pellets were hydrolyzed in 6 N HCl at 105^{o}C for 18 hours. The amount of hydroxyproline was calculated using the standard curve of hydroxyproline (CAS No. 51-35-4, Sigma-Aldrich) at an absorbance of 550 nm. The collagen content was calculated using a conversion factor of 7.25.

Nutrient composition measurement

Meat samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), and ash using AOAC methods (AOAC, 2005). DM was determined by drying the samples at 105 ℃ in a hot air oven. CP and EE were determined by the Kjeldahl method and the Soxhlet extraction method, respectively. Ash was determined at 550 ℃ for 6 hours in a furnace.

Statistical analysis

Data were expressed as mean ± standard deviation. Differences were tested by oneway analysis of variance to compare the studied traits of dairy steer meat which came from dairy steers of 3 treatments fed with different starch sources in concentrates. To determine the differences between the mean of two treatments, Duncan's new multiple range test was performed. The values $P < 0.05$ were considered statistically significant. Statistical analysis was done using SPSS version 16 (SPSS Inc, Chicago, IL, USA).

Results

Meat quality and texture profile

The effects of the starch sources in the concentrates on meat quality are shown in Table 1. The pH values of the three groups were similar (P>0.05) and were 5.52, 5.55, and 5.53 for CO, CA, and PI groups, respectively. There was no difference in meat color among the three groups (P>0.05). Although, there were no significant differences (P>0.05), the CO group showed slightly lower thawing loss than CA and PI groups. There was no significant difference in cooking loss among treatments. Shear force was not significantly different among the different starch sources of concentrate (P>0.05). Texture profile did not differ among treatments (P>0.05), but CO group appeared to have the highest hardness, while PI group appeared to have the highest hardness.

Table 1. Effect of starch source of concentrate on meat quality and texture profile of fattening dairy steers

Parameter	Starch source[1] (Mean ± SD)			P value
	CO	CA	PI	
Meat quality				
pH	5.52±0.91	5.55±0.10	5.53±0.07	0.792
L*	38.32±3.32	40.77±2.27	40.58±1.03	0.145
a*	1 6.36±1.17	16.05±1.46	16.77±1.72	0.680
b*	14.61±1.49	14.56±1.11	14.54±1.25	0.995
Thawing loss (%)	2.62±0.74	3.10±1.56	3.53±1.30	0.540
Cooking loss (%)	18.64±3.50	20.24±2.70	19.91±2.12	0.564
Shear force (kg)	5.91±1.52	5.19±0.20	5.12±0.80	0.312
Texture profile analysis				
Hardness (N/cm^2)	35.58±17.60	39.21±26.30	47.97±23.88	0.587
Springiness (cm)	1.00±0.00	1.00±0.00	1.00±0.00	0.740
Chewiness (N/cm^2)	20.71±10.98	21.43±11.81	24.67±13.15	0.810
Cohesiveness (N/cm)	0.58±0.06	0.59±0.06	0.55±0.04	0.464
Gumminess (ratio)	21.98±11.88	21.43±11.81	25.55±12.83	0.800

[1] CA = ground cassava; CO = ground corn; PI = pineapple stem starch.

Nutrient composition

There were no differences in protein content (P>0.05), which the average was 23.5%. Moisture content did not differ among treatments (P>0.05) and the average was 66.1%. Ash content of PI group was significantly higher than that of CO and CA groups (P<0.05) and there were 1.24%, 0.94%, and 0.91%, respectively. Although the fat content was not significantly different among treatments (P>0.05), CA group appeared to have a higher fat content than CO and PI groups, there were 11.49%, 9.74%, and 9.82%, respectively. The fat content of PI and CO groups tended to be lower than that of CA group.

Table 2. Effect of starch source of concentrate on nutrient composition and collagen content of fattening dairy steers

Nutrient composition	Starch source[1] (Mean ± SD)			P value
	CO	CA	PI	
Protein (%)	23.31±1.70	23.34±1.59	23.83±1.44	0.789
Moisture (%)	65.75±1.93	65.72±1.80	66.85±2.32	0.522
Ash (%)	0.94^{b}±0.22	0.91^{b}±0.21	1.24^{a}±0.28	0.039
fat (%)	9.74±1.46	11.49±2.35	9.82±2.94	0.344

[1] CA = ground cassava; CO = ground corn; PI = pineapple stem starch.

Collagen solubility

There was no significant (P>0.05) effect of starch source in concentrate on collagen content including soluble collagen, insoluble collagen, total collagen, and collagen solubility in meat.

Table 3. Effect of starch source in concentrate on collagen solubility of fattening dairy steers meat

Parameter	Starch source[1] (Mean ± SD)			P value
	CO	CA	PI	
Collagen content (mg/g wet weight)				
Soluble collagen	0.55±0.11	0.57±0.03	0.54±0.13	0.871
Insoluble collagen	3.45±0.56	4.15±0.16	3.98±0.98	0.209
Total collagen	3.45±0.62	4.72±0.16	4.52±1.09	0.265
Collagen solubility (%)	13.82±2.27	12.16±0.86	11.99±1.44	0.125

[1] CO = ground corn; CA = ground cassava; PI = pineapple stem starch.

Discussion

In this study, there was no effect of starch sources on muscle pH, meat color, thawing loss, cooking loss, shear force, and meat texture. Hattakum *et al*.

(2019) investigated the effects of three different feed sources: Napier silage, whole corn silage, and pineapple by-product silage used at the same level in the total mixed ration (TMR) on meat quality of Holstein steers. They reported that nitrogen free extract or carbohydrate in TMR was higher when pineapple by-product silage was used as feed source, but crude fiber was lower. However, they found no significant effect of feed sources in TMR on muscle pH, meat color, drip loss, thawing loss, cooking loss, and shear force. Pintadis *et al*. (2020) investigated the effects of concentrate intake and pineapple stem by-product as roughage source on meat quality of Holstein steers. They reported that the intake of pineapple stem by-products decreased with increasing concentrate content. However, no significant effect of concentrate intake was found on meat traits pH, color, thawing loss, cooking loss, and shear force. The only significant effect of concentrate percentage found in their study was drip loss, which increased with increasing concentrate percentage. Bunmee *et al*. (2012) reported that culled dairy cows slaughtered immediately after culling or others fed a 12-week finishing period with three different diets containing only corn silage as the forage group, a high-energy group (cassava pulp + corn silage) and a low-energy group (crude rice bran + corn silage) had no significant differences in meat color, drip loss, thawing loss and cooking loss. However, it was found that shear force tended to be lower in the high energy feeding group than in the other groups. Texture profile analysis revealed that the sources of starch in the concentrate had no effect on the instrumental texture parameters of hardness, springiness, chewiness, cohesiveness, and gumminess. This is in agreement with Salami *et al*. (2021) who reported that three concentrate supplements containing either barley/soybean meal, corn dried distillers' grains with soluble, or wheat dried distillers' grains with soluble had no significant effect on the texture profile parameters of *Longissimus thoracis* muscle of cattle.

In this study, there was no effect of starch sources in the concentrate on nutrient composition; protein, moisture, and fat of LT meat of Holstein steers, except meat from PI group had higher ash content than the others. This is in agreement with Hattakum *et al*. (2019) who found no significant effect of feed sources on fat and moisture content. Moreover, Pintadis *et al*. (2020) reported that concentrate level also had no effect on fat and moisture content. In the present study, fat content ranged from 9.73% to 10.54% and moisture content ranged from 65.72.3% to 66.85%, which were within the range of Hattakum *et al*. (2019) but higher than the results of Pintadis *et al*. (2020) who found fat content ranged from 4.99% to 6.43% and moisture content ranged from 63.3% to 64.3%. The possible explanation for the difference between the experiments could be the variation in feed, animals, and fattening period. Bunmee *et al*.

(2012) reported that culled dairy cows fed high and low energy diets had higher meat fat content than the forage group, while meat protein and moisture were not affected by the treatments. Salami *et al*. (2021) reported that three concentrate supplements containing corn dried distillers' grains with soluble had higher protein content in meat but lower ash content than concentrates containing either barley/soybean meal or wheat dried distillers' grains with soluble feeding groups, while fat and moisture content in meat were not affected by the treatments.

Consumer perception of meat quality is influenced by the tenderness of the meat. Collagen is a connective tissue protein that contributes to meat tenderness and differences in texture. The tenderness of meat is determined by the type, structure, and amount of connective tissues such as collagen and elastin (Lepetit, 2008). Purslow, (2005) found that either the amount of collagen or its heat solubility can affect the toughness of meat. In this study, there was no significant effect of starch source in the concentrate on collagen content, including soluble collagen, insoluble collagen, total collagen, and collagen solubility. This may be a possible explanation for the non-significant difference in shear force between the treatment groups. This is in agreement with Bunmee *et al*. (2012) who reported that feeding cull cows high energy forage, low energy forage, or green forage had no effect on soluble, insoluble, and total collagen contents. However, Archile-Contreras *et al*. (2010) found lower total collagen content in cattle fed corn than in cattle fed pasture and explained this by the fact that more myofibrillar protein was deposited in corn-fed cattle, diluting collagen content. However, no significant effect of the diet on collagen solubility was found. Cox *et al*. (2006) reported similar values of collagen solubility when comparing forage and grain diets. However, several studies have found that cattle fed high-energy diets have a faster protein turnover, presumably due to their rapid growth, and therefore their meat should contain a higher proportion of newly formed, heat-soluble collagen (Miller *et al*., 1987; Wu *et al*., 1981).

It is concluded that the effects of the three starch sources of the concentrate did not affect meat quality, texture profile, collagen solubility, and nutrient composition; protein, moisture, and fat but affected on ash content of LT muscle of Holstein steers.

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