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Application of By-Products from Agriculture and Food-Processing as Feed Resources for Ruminants

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ABSTRACT

In Taiwan, millions of livestock are raised for animal protein supply, however most of the feed ingredients are imported. For food safety and sustainable environment, exploring the available locally produced feed resources is more and more urgent. There are lots of by-products produced from agriculture and food processing. The previous and ongoing utilization research work are introduced in this paper. The high moisture content (> 90%) of pineapple pulp (PP) restricts its utilization. It was suggested that PP could be mixed with the drier source like rice straw (RS), wheat bran (WB) or Flammulina velutipes (FC) spent substrate. Diet containing 12 kg a day of fresh PP+RS silage supported normal milk yield and milk fat percentage for Holstein cows. Unfortunately, PP sugars were almost used up by lactic acid bacteria when ensiling. No response to our high milk protein and gravity expectation, but PP+WB still performed as a good alternative feed source that 8% in lactating goats diet was suggested. The proper adding ratio in diet for PP+FC silage for milking goats was 8%, and for Holstein cows 8% to 12% was suitable. Some by-products possess negative effect as feed to livestock and need awareness. About 15% of sweet potato harvested was discarded as sub-quality sweet potato (SSP). It still holds strong trypsin inhibitor (TI) activity. By ensiling, 28.7% of the TI activity was diminished. When SSP+WB silage directly added into diets to occupy 13.5% diet dry matter, it caused a significant 10% decrease in milk fat percentage that rumen acidosis was recognized. Another case was the feeding of tomato pomace+corn meal silage. Lactating goats accepted when added into diets from 6% to 10% dry matter, however, cows responded poorly. How high the by-products could be suitably adopted in diets for milking ruminants was evaluated. Formulated by commonly used by-products, the 333 diet is recommended so that mid to high-lactating cows could keep their performance including by-products from 10% to 32%. Besides offering as an alternative feed resource,adoption of by-products in diets also showed the benefits in decreasing greenhouse gas emission and health improvement. Rumen methane emission numerically decreased by 9% and 22% and carbon dioxide by 10% and 13% when diets having 10%, 20% or 32% by-products (Rusitec) are implemented. The off-bottom of mushroom during shaping process was fed to goat kids around weaning. Off-bottom from Pleurotus eryngii and Flammulina velutipes added at 1.5% each in diet stimulated the best daily gain and had significant lower diarrhea occurrence. Agriculture and food processing by-products are valuable feed resources. More studies are needed to confirm the proper preserving, wrapping technique, efficient transportation, nutrition balance knowledge, and its price.It is planned to set up the whole industry link that could really establish the business.

Keywords: By-products from agriculture and food-processing, feed, Holstein dairy cow, Sannan and Alpine dairy goat

INTRODUCTION

By-products are important sources of feed for ruminants. Wet brewer's grains, sorghum distillers' grains, soybean pomace, wheat bran, and pelleted soybean hull all are commonly used in diets. There are lots of by-products with low quality, short season, small quantity, or high in water content and thus are discarded. This is worth our awareness to change. The 2016 Agricultural Statistics Yearbook of Taiwan indicated that the planted areas of rice are about 27.5 million hectares, and is estimated that about 5 - 6 tons of rice straw are produced in each hectare (Tien *et al*., 2013); therefore, the production of rice straw can reach above 150 million tons in Taiwan. Rice straw is not an easily digestible high fiber by-product because it contains 25% - 45% of cellulose, 18% - 30% of hemicellulose, and 10% - 15% of lignin (Van Soest, 2006). Traditionally, it can be used as a feed ingredient in ruminants but shows lower animal performance (Van Soest, 2006; Sheikh *et* al., 2017). The edible mushroom could secrete enzymes to decompose lignin, including laccases, manganese peroxidase, and lignin peroxidase (Hammel *et al*., 1993; Martínez *et al*., 2005). It is estimated that 20 million tons of spent mushroom substrates are produced annually (Chen *et* al., 2013), which caused an urgent problem for farmers to deal with plenty of mushroom waste substrates.

Pineapple pulp is the residue from pineapple cake, cans or juice processing factories. It was estimated that the pineapple pulp occupied about 25% to 33% of the whole pineapple fruit. In the 2016 data, there were 400,000 tons of pineapples harvested. This means about 100,000 tons to 130,000 tons of pineapple pulp were produced (Guerout, 1975). Sweet potato is an energy source and is rich in starch. Diverse products from sweet potato are more and more popular in the food market. The planting area is stably increasing and reaches 10,310 hectares. Yearly production quantity comes to 241,694 tons. Around 15% of sweet potato harvested was graded off due to its size or shape. The quantity of sub-quality sweet potato could reach 36,254 tons per year and the handling pressure is high. The activity of anti-nutrient factor trypsin inhibitor is high in sweet potato. From previous studies, ground rice grain and sweet potato were used in feeding trials to replace the imported corn. Results suggested that except for the layers, ground rice grain could replace 50% to 100% of corn in diets. But due to trypsin inhibitor, sweet potato could only replace 20% to 30% of corn in diets to avoid growth retardation. The usage of sweet potato in monogastric livestock is highly restricted. It is wondered if going through acidic ensiling process and rumen microbe degradation, could destroy trypsin inhibitor. Related studies are still in progress.

UTILIZATION OF BY-PRODUCTS AS FEED SOURCES

Pineapple pulp

Pineapple pulp (PP), which is rich in water soluble carbohydrates (ca. WSC 26%) and fiber (ca. NDF 43%), is the residue from pineapple cake and juice processing. The high moisture content (> 90%) limits its preservation, transportation, and utilization as feeds. Before making PP into good silage, it is necessary to run *in vitro* screens to get the proper mixing formulations. Highly fibrous spent mushroom substrate and rice straw (RS) are drier and might be improved when mixed with the acidic PP during ensiling. PP and *Flammulina velutipes* (FC) spent substrate were formulated into eight ratio silages (PFS) and 1:1 ratio (fresh weight) was recommended from its Flieg's scores, compositions, *in vitro* dry matter digestibility, and physical appearance. Same for PP and RS *in vitro* study,10:1 mixing ratio (PRS) was chosen. And for wheat bran, the 6:1 ratio (PWS) was adopted for following animal evaluation trials (Fan *et al*., 2014a).

In a PRS study, a total of 40 mid-lactating Holstein cows were assigned into fourgroups for replicate feeding trials each last for 28days. Four treated diets balanced for nutrition requirement included fresh PRS at 0, 4 kg, 8 kg, or 12 kg per day per cow. Results showed that cow performance fed with four diets were all similar (Table 1). The averaged dry matter intake, milk yield, percentage of milk fat, milk protein, total solids, milk urea nitrogen, and somatic cell counts were all close among groups, there were 18.1 kg, 23.3 kg, 3.80%, 3.41%, 12.73%, 12.4 mg/dL, and $26.3*10^4$/mL, respectively. Going through proper ensiling technique, the feeding values of pineapple pulp and rice straw could be effectively promoted. Addition of PRS up to 12 kg a day is acceptable for mid-lactating Holstein cows (Chang *et al*., 2018).

Table 1. Effect of supplementation of PRS in diets on lactating performance of Holstein cows

Traits	Levels of PRS added into diets (as fed basis)			
	0 kg	4 kg	8 kg	12 kg
Daily dry matter intake, kg	18.1	17.8	18.7	17.7
Daily milk yield, kg	22.5	23.8	23.2	23.5
Milk fat, %	3.89	3.65	3.86	3.79
Milk protein, %	3.44	3.38	3.48	3.34
Income over feed cost, %	100	106	102	105

PRS was mixed from pineapple pulp and rice straw at 10:1 fresh weight ratio.
All traits performances were similar among treatments ($P > 0.05$).

In Taiwan, the lower fat level and specific gravity of goat milk during hot summer is a problem. High starch and sugar might stimulate the milk fat and protein synthesis. In PWS study, PP holding high WSC and fiber together was expected to solve the above-mentioned problem. A total of 21 individually fed lactating Alpine goats with daily milk yield above 2.2 kg were assigned into 28-d feeding trials twice in summer. The diet included corn silage as major forage, grain mixture, and by-product. Control diet had 8% of wheat bran, and by substituting the wheat bran, PWS was added into trial diets at 4 or 8% of diet dry matter. Results showed that dry matter intakes (averaged 2.07 kg), milk yield (2.66 kg), milk specific gravity (1.0305), milk fat (3.67%), milk protein (3.30%), milk lactose (4.07%), milk total solids (11.73%), and milkurea nitrogen (26.0 mg/dL) were similar among groups (Table 2). The WSC of PP was largely degraded by lactic acid bacteria during ensiling, from 26% to 1%. Although PWS added into diet by 4% to 8% could not effectively promote the milk fat and gravity in summer, it had shown to be a valuable local feed resource for lactating dairy goats. A diet with 8% PWS is recommended (Fan *et al*., 2018).

Table 2. Effect of supplementation of PWS in diets on lactating performance of Alpine goats

Traits	Levels of PWS added into diets (dry matter basis)		
	0%	4%	8%
Dry matter intake, kg/d	2.00	2.09	2.14
Daily milk yield, kg	2.59	2.69	2.70
Milk fat, %	3.65	3.64	3.71
Milk protein, %	3.33	3.29	3.27
Milk specific gravity	1.0306	1.0306	1.0303
Income over feed cost, %	100	105	104

PWS was mixed from pineapple pulp and wheat bran at 6:1 fresh weight ratio.
All traits performances were similar among treatments ($P > 0.05$).

Feeding values of PFS were evaluated from two lactation trials, dairy goats and Holstein cows. PFS was constituted by pineapple pulp and spent *Flammulina velutipes* substrate at 1:1 fresh weight ratio. Individually fed Saanen and Alpine goats and groupfed Holstein cows were assigned into 28-d feeding trials twice. Control diet used corn silage and pangola grass hay as main forage. By substituting the main forage, PFS was added into trial diets at 4, 8 or 12% diet dry matter. Results showed that the dry matter intake and milk yield of goats fed with 4% PFS were higher than those fed with 12% PFS diet ($P < 0.05$, Table 3). However, goats fed with 4% PFS diet had the lower milk fat percentage than the other groups ($P < 0.05$) (Fan *et al*., 2014b). For Holstein cows, intake (averaged 18.8 kg), milk yield (averaged 23.5 kg), and milk compositions were all similar among groups. In conclusion, the combination of PP and FC at 1:1 ratio is a proper formulation for these two by-products of high quantity. PFS could be an alternative feed source for lactating dairy goats and Holstein cows. A diet with 8% PFS is suggested for lactating dairy goats and diets containing 8% to 12% of PFS are suitable for Holstein cows (Chang *et al*., 2014).

Table 3. Effect of supplementation of PFS in diets on lactating performance of dairy goats and Holstein cows

Traits	Levels of PFS added into diets (dry matter basis)			
	0%	4%	8%	12%
Saanen/Alpine goats				
Daily dry matter intake, kg	2.29 ^{ab}	2.44 ^{a}	2.25 ^{ab}	2.09 ^{b}
Daily milk yield, kg	2.30 ^{ab}	2.40 ^{a}	2.32 ^{ab}	2.20 ^{b}
Milk protein, %	3.19	3.09	3.17	3.12
Milk fat, %	4.06 ^{a}	3.75 ^{b}	4.08 ^{a}	4.16 ^{a}
Income over feed cost, %	100	97	103	102
Holstein cows				
Daily dry matter intake, kg	19.2	17.6	18.6	19.9
Daily milk yield, kg	23.5	22.6	23.8	24.1
Milk protein, %	3.35	3.33	3.32	3.24
Milk fat, %	3.61	3.54	3.52	3.50
Income over feed cost, %	100	99	103	103

PFS was mixed from pineapple pulp and spent *Flammulina velutipes* substrate at 1:1 fresh weight ratio andwas added by substituting major forage corn silage and pangola grass hay.

$^{a, b}$ means in the same row with different superscripts differed significantly ($P < 0.05$).

The proper formulation strategy of sub-quality sweet potato

Sweet potato products are more and more popular in human food markets. Due to strict quality control, it is estimated that 15% of sweet potatoes are discarded because of their shapes or sizes. This off part resulted in proximately 36,254 tons a year. Sweet potato provides rich starch like corn. It was aimed to explore the proper ensiling method for sub-quality sweet potato (SSP) and the proper formulation way in diets for ruminantsto promote its recycling application.

In the first-year study, SSP mixed silage constituted by SSP and wheat bran (SSP+WB) at 10:1 fresh weight ratio was used in the Holstein lactating cows feeding trial.By substituting the by-product part in the diet, wet brewer’s grains and soybean hull pellet, SSP+WB silage were added into diets to occupy 0, 4.5%, 9%, or 13.5% of dietary dry matter. It was equal to 0, 3, 6, or 9 kg per day per cow as fed basis. The same grain concentrate containing about 60% of corn was offered to all four groups. A total of 28 Holstein cows with daily milk yield above 23 kg were randomly assigned into four groups and raised in the wet-padding ventilation barn for 24-day feeding trial which were done twice.

SSP has the high potency of anti-nutrient factor trypsin inhibitor and needs awareness. It was shown in this study that the ensiling process could effectively decrease the trypsin inhibitor activity of SSP by 28.7%. Regarding the response from cows, the main effect from adding SSP+WB silage was shown in the lowered milk fat percentage (Table 4, Fig. 1). Contrast comparison showed milk fat percentage decreased by 9.7% between control group and SSP+WB added three groups (3.76 vs. 3.40%, $P = 0.023$). Dry matter intake and milk yield were tended to increase following the increasing ratio of SSP+WB in diets. Dry matter intake of cows increased by 16% (19.6 kg vs. 22.8 kg, $P = 0.023$). Milk yield had shown improvement trend but not significant (10%, 24.1 vs. 26.5 kg, $P = 0.31$). The intake and lactating responses were postulated as the results of low fiber and high starch content in SSP+WB diets. Comparing to the control, neutral detergent fiber (NDF) in SSP+WB 13.5% diet decreased by 24% from 42.2% to 32.1% and non-fibrous carbohydrates (NFC) on the contrary increased sharply by 38% from 31.0% to 42.8%. The most concern is the lower milk fat percentage which has strong correlation with rumen acidosis (Lee *et al*., 2019). To avoid the rumen health problem, in the second-year study, the SSP+WB silage was added into diets by substituting the corn in grain mixture. Feeding trial is in progress.

Table 4. Effect of supplementation of SSP silage in diets on lactating performance of Holstein cows (1st year study).

Traits	Levels of SSP added into diets (dry matter basis)			
	0%	4.5%	9.0%	13.5%
Daily dry matter intake, kg[1, 2]	19.4 [b]	20.4 [ab]	21.9 [ab]	23.0 [a]
Daily milk yield, kg	24.1	25.1	25.4	26.5
Milk protein, %	3.64	3.42	3.61	3.58
Milk fat, %[1, 2]	3.76 [(a)]	3.39 [(b)]	3.45 [(b)]	3.35 [(b)]

SSP silage was mixed from sub-quality sweet potato and wheat bran at 10:1 fresh weight ratio. The pH, dry matter, crude protein, neutral detergent fiber and *in vitro* dry matter digestibility were 4.12, 28.5, 9.2, 22.8, and 80.7% (dry matter basis). SSP silage was added by substituting by-product in diets.

[1] Two statistic methods were used, CRD w/ covariate and Contrast, 0% vs. 4.5 – 13.5% groups.

[2] From Contrast comparison, dry matter intake ($P = 0.03$) and milk fat percentage ($P = 0.02$) both reached significant level.

[a, b] means in the same row with different superscripts differed significantly ($P < 0.05$); [(a), (b)] $P = 0.13$.

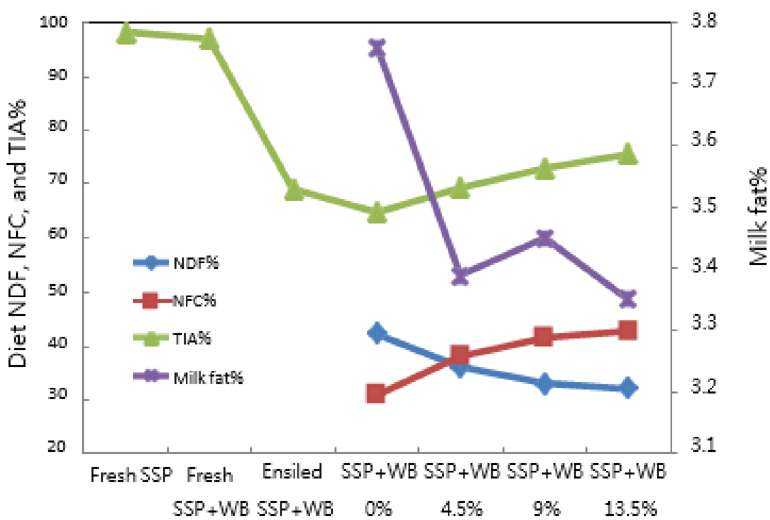

Fig. 1. The diet compositions, trypsin inhibitor activity (TIA) of SSP+WB diets, and milk fat percentage responses of Holstein cows in the 1st year study

Goats and cows respond to tomato pomace silage differently

Tomato pomace is the residue from ketchup or tomato juice processing. However, the high moisture content limits its transportation and preservation for feeds. To build up a friendly environment, the ensiling formula for tomato pomace and its proper usage in diets for lactating goats and cows were studied Tomato pomace and corn meal (TPC) were mixed at 10:1 fresh weight ratio and ensiled in big plastic bags. TPC had pH value of 3.71 and both dry matter and crude protein contents of 20%, respectively. A total of 20 heads of Saanen and Alpine goats were randomly assigned into four groups and raised in individual pens in a 28-d feeding trial. TPC silage was added into four treatment diets at 0, 6, 10 or 15% (DM basis) by substituting part of the distiller's grains and corn in control diet. Results showed that four diets could support goats to have similar daily dry matter intake (1.91 to 2.03 kg), milk fat (avg. 4.32%), protein (avg. 3.20%), lactose (avg. 4.31%) and total solid (avg. 12.53%). Milk yield from goats fed with 15% TPC silage diet was numerically lowered (2.34, 2.51, 2.58 and 2.24 kg). This trend was even obvious when expressed as 3.5% fat-corrected milk yield, 2.59, 2.78, 2.96, and 2.59 kg. In conclusion, tomato pomace could be well preserved when mixed with corn meal at 10:1 ratio. Diets supplemented with 6% to 10% tomato pomace+corn meal mixed silage had no negative effect on the lactating performance of dairy goats and 10% inclusion was recommended (Table 5) (Fan *et al*., 2015).

However, when diets with 0 – 15% TPC silages were offered to Holstein cows, responses were different. Cows fed with diets with TPC silage decreased their milk yield by 5%, decreased milk protein percent (Contrast statistic, $P < 0.05$) and increased milk urea nitrogen ($P < 0.06$, Table 5). Reason for the negative response was not known. Tomato pomace+corn meal silage is not a suitable feed for lactating Holstein cows shown in this study.

Table 5. Effect of supplementation of TPC silage in diets on lactating performance of dairy goats and Holstein cows

Traits	Levels of TPC added into diets (dry matter basis)			
	0%	6%	10%	15%
Saanen/Alpine goats				
Daily dry matter intake, kg	1.91	1.95	2.03	1.91
Daily milk yield, kg	2.34	2.51	2.58	2.24
FE, milk/intake	1.23	1.29	1.27	1.24
Milk fat, %	4.22	4.19	4.33	4.54
Milk protein, %	3.11	3.23	3.21	3.24
Holstein cows				
Daily dry matter intake, kg	19.3	18.4	18.2	17.9
Daily milk yield, kg	25.7	24.9	24.2	24.2
FE, milk/intake	1.33	1.35	1.33	1.35
Milk fat, %	3.76	3.68	3.60	3.85
Milk protein, % [1]	3.38	3.17	3.23	3.28
Milk urea nitrogen, mg/dL [2]	13.1	14.3	14.1	13.7

TPC silage was mixed from tomato pomace and corn meal at 10:1 fresh weight ratio.
[1] Milk protein percentage was lowered in TPC groups versus not added control group ($P < 0.05$) when Contrast statistic was applied.
[2] Milk urea nitrogen level was higher in TPC groups versus not added control group ($P < 0.06$) when Contrast statistic was applied.

The level of by-products in diets

Many by-products have high amount of short fiber and high digestibility at the same time. This makes it possible to partially replace the long-fiber forage and the high-starch grain mixture in diets. And this would contribute to a decrease in heat increment of forage when digested and avoid rumen acidosis problem when grain feeding is high. This characteristic is important for cows in Taiwan especially in the hot and humid summer. In 2011, before summer season, our experiment dairy barn was remodeled for sprinkler and fan system and the high by-product 333 diets was offered. Diets for lactating cows were formulated to have approximately 1/3 of forage, 1/3 of by-product, and 1/3 of grain mixture. After these two-heat stress relieving strategies were applied, herd average milk yield increased 3.8 kg per day per cow when comparing with the previous 2010 year (diet contained about half forage and half grain) from June to September. It was postulated that the more comfortable barn environment and 333 high by-product diet stimulated the feed intake more and kept the healthier rumen.

To officially identify if the 333 diet could be used for lactating cows, a total of 30 mid-lactating Holstein cows were randomly assigned into three diets including by-product at 10%, 20%, or 32% in dietary dry matter. By-products commonly used were wet brewer’s grains, sorghum distiller’s grains, soybean hull pellet, and wheat bran. Feeding trial lasted for 28 days and was replicated once. Results indicated that dry matter intake, milk yield, and milk efficiency were all similar for cows fed with three levels of by-products. The performance was averaged 19.2 kg, 22.5 kg, and 1.17, respectively. Milk compositions and income over feed cost both were also not affected by by-product levels in diets (Table 6). These results implicated that for mid-lactating Holstein cows diet formulated with 30% by-product was acceptable.

Table 6. Effect of addition levels (10% – 32% dietary dry matter) of agricultural and food processing by-products on the milking performance of mid-lactating Holstein cows

Traits	Control By-products 10%	By-products 20%	By-products 32%
Dry matter intake, kg/d	19.6	19.1	18.9
Milk yield, kg/d	22.7	22.1	22.7
Milk efficiency, milk/intake	1.16	1.16	1.20
Milk fat, %	3.57	3.67	3.58
Income over feed cost, %	100	97	101

All traits performances were similar among treatments (P > 0.05).

To further understand the replacement influence of by-products to grain mixture, diets with fixed forage ratio 36% were designed to have control 333 diets, high by-product diets (37%, grain was cut to 27%), and high grain diets (37%, by-product was cut to 27%). Both high-producing Holstein cows and mid-producing Alpine goats were assigned in the replicate feeding trials. Results indicated that all trait performances were similar among the three groups for both cows and goats (Table 7). By-products combined with wet brewer's grains, sorghum distiller's grains, soybean hull pellet, and wheat bran with high digestibility are of high feeding values. It is feasible to use them up to the high level 37% in diet and has no adverse influence (Lee *et al.*, 2012; Fan *et al*., 2012).

Table 7. Effect of replacing grain mixture by agricultural and food processing by-products in low long fiber diets on the lactating performance of Holstein cows and Alpine goats.

Traits	Control 36 F : 32 B : 32 G	High by-products 36 F : 37 B : 27 G	High grains 36 F : 27 B : 37 G
Holstein cows			
Dry matter intake, kg/d	21.7	22.1	22.3
Milk yield, kg/d	31.1	31.1	31.7
Milk fat, %	3.65	3.54	3.56
Alpine goats			
Dry matter intake, kg/d	1.76	1.86	1.84
Milk yield, kg/d	2.29	2.19	2.38
Milk fat, %	4.04	3.97	3.90

F: forage, B: by-products, G: grain, in dietary dry matter basis.
All traits performance were similar among treatments (P > 0.05).

MITIGATION OF GREENHOUSE GAS FROM RUMEN (RUSITEC STUDY)

Utilization of local feedstuffs can reduce the carbon footprint of meats, milk, and eggs, from saving on the feed transportation and waste disposal. Agricultural and food processing by-products proved to be valuable alternative feed resources for ruminants. Rumen is a big anaerobic fermentation tank that continuously produce high amount of methane. To reduce the global warming impact caused by ruminants the feed manipulation is thought to be one way of reducing the methane emission from rumen. The effect of adding by-products into diets on the methane emission were studied by means of the Rusitec (Rumen simulation techniques) system. Agricultural and food processing by-products, wet brewers' grains, sorghum distillers' grains, soybean hull pellet and wheat bran, were added into diets at 10%, 20% or 32% of dietary dry matter. Local corn silage, pangola grass hay and low amount of imported alfalfa hay constituted the forage part and the other was corn-soybean grain mixture. Trial diets were fermented in the semi-continuous anaerobic fermentation system Rusitec for 10 to 12 days. Except for the daily change of feed bag, fermentation gas was collected in gas bags and analyzed for methane and carbon dioxide by gas chromatograph. Results showed that the daily averaged pH values of fermentation liquid were 6.35, 6.34 and 6.30, and dry matter digestibility of three diets were 84.3%, 86.5% and 84.7%, respectively. Efficiencies of rumen microbial synthesis (g-microbe/g-organic matter disappearance) tended to increase, 0.50, 0.55 and 0.58. Quantity of daily fermentation gases were 2.65, 2.53 and 2.50 L, respectively. The daily emission of methane and carbon dioxide tended to reduce following the increasing proportion of by-products in diets (Table 8). Comparing 20% and 32% by-products with 10% by-products diets, daily output of methane numerically reduced by 9% and 22%, and for carbon dioxide 10% and 13% reached, respectively. From this Rusitec study, it is recommended that the diet strategy of using higher level of local agricultural and food processing by-products is a beneficial way to reduce the greenhouse gas impact from ruminant raising (Lee *et al*., 2016).

Table 8. Effect of using agricultural and food processing by-products into diets on the methane and carbon dioxide emission amount from the rumen (Rusitec study)

Items	10% by-products	20% by-products	32% by-products
Methane emitted, mg/day	248 (100%)	226 (91%)	193 (78%)
Carbon dioxide emitted, g/day	2.68 (100%)	2.42 (90%)	2.35 (87%)

All traits performances were similar among treatments (P > 0.05).

PROMOTING THE HEALTH OF WEANING GOATS

It is suggested that polysaccharides, triterpenoids, polyphenols, and flavonoids in mushrooms might benefit the health of weaning goats. During the processing, shaping will cut off some bottom part of the mushroom. This off-bottom was estimated to have 1/10 of the whole mushroom weight and resulted in about 7,000 tons fresh weight a year. Effect of the supplementation of mushroom bottom by-products in diets on the growth performance and immune response of dairy goat kids around weaning period was evaluated. Mushroom off-bottoms from *Pleurotus eryngii* and *Flammulina velutipes* were dried and ground. A total of 40 heads of 4-wk-old kids were randomly assigned into four groups for a 12-wk feeding trial. All kids received 150 g milk replacer in one liter per day until 8-wk-old. A corn-soybean meal basal diet was offered as the control group. Three supplemented groups were fed with diets supplemented with 3% of *Pleurotus eryngii*, 3% of *Flammulina velutipes*, or the mixture of 1.5% *Pleurotus eryngii* and 1.5% *Flammulina* velutipes mushroom off-bottom. Feed and water were offered ad libitum. Growth performances and diarrhea index were measured. Results showed that kids fed with four diets had similar feed intake and feed conversion rate. Supplementation of mushroom off-bottom increased the daily body weight gain, and kids fed with the mixture diet achieved the higher gain compared with control group (P < 0.05, Table 9). Daily gains of kids in four groups were 146, 160, 165, and 173 g, respectively. Diarrhea index of kids showed the same trend that supplementation of mushroom off-bottom could decrease the occurrence of diarrhea. Diarrhea index decreased obviously (P < 0.05) on kids fed with 3% *Flammulina velutipes* and the mixture mushrooms off-bottom diets during the 9^{th} to 12^{th} weeks of experimental period compared with the control group. In conclusion, supplementation of the 1.5% of *Pleurotus eryngii* and 1.5% of *Flammulina velutipes* mushrooms off-bottom for goat kids is effective in improving their growth and health status (Shih *et al*., 2017).

Table 9. Effect of supplementation of mushroom off-bottom in diets for weaning goat kids on their growth performance and immune capacity

Items	Control	3% *Pe*	3% *Fv*	1.5% *Pe*+1.5% *Fv*
No. of kids	10	10	10	10
Daily feed intake, g	453	478	451	521
Daily BW gain, g	146 ^{b}	160 ^{ab}	165 ^{ab}	173 ^{a}
FE, intake/gain	3.10	2.98	2.78	3.01
Diarrhea index,9th-12th wk	1.56 ^{a}	1.42 ^{ab}	1.18 ^{b}	1.08 ^{b}

Pe: *Pleurotus eryngii*, *Fv*: *Flammulina velutipes.*
$^{a,\ b}$ means in the same row with different superscripts differed significantly ($P < 0.05$).
There are five levels for diarrhea index, the lower the normal appearance.

CONCLUSION

For the past 15 years, global prices for feed ingredients and hay had increased sharply, causing higher production cost and food security concern. Therefore, the need to explore available feed resources becomes more and more important. From our studies, ensiling could be one economical way to preserve locally produced agricultural and food processing by-products as feeds for ruminants. Improving the feed values of some fibrous but high quantity residues is also an effective way to expand feed sources. Through the proper combination of by-products and the nutrition balance knowledge, all will influence the utilization of by-products. Not only the feed character, but by-products could also be helpful to livestock health and decreases the food mileage by means of lower methane emitted from the rumen. Rice straw, pineapple pulp, spent mushroom substrate, sub-quality sweet potato, tomato pomace, and so on all could be properly formulated into silage for feeding ruminants. More research work is needed. Soon, we would like to try different sizes and formulas for by-products preserved as plastic wrapped round bales. It is believed that the diverse bale silage could promote the convenient transportation and hence set up the industry links, from production place to farms.

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AUTHORS' CONTRIBUTIONS

G.J.F. performed the goat study, C.T.C. performed the cow study, T.F.S. performed cow management and by-product preparation, and C.F.L. designed research and wrote the paper.

COMPETING INTERESTS

GJF, CTC, TFS, and CFL declare that they have no conflict of interests.