Trop Anim Health Prod (2015) 47:557–561
DOI 10.1007/s11250-015-0762-2

REGULAR ARTICLES

Study on evaluation of silage from pineapple (*Ananas comosus*) fruit residue as livestock feed

Nisarani Kollurappa Shivakumar Gowda · Naglapura Chandrashekara Vallesha · Vaibhav Bhagvan Awachat · Samireddypalli Anandan · Din Taran Pal · Cadaba Srinivasa Prasad

Received: 4 June 2014 / Accepted: 9 January 2015 / Published online: 30 January 2015

Abstract Pineapple is a commercially important fruit crop grown in Asian and African countries. Pineapple fruit residue (PFR) accounts for more than 65 % of the processed fruits, and its disposal is a major problem due to its high moisture and sugar content predisposing it to fungal growth and spoilage. Silage technique was adopted to address this problem, and the PFR silage was evaluated for its feeding value. It was observed that on 15th day, the pH of PFR silage was 4.2–4.3 and lactic acid content was 6–8 % (DM basis). Combination of 4 parts leafy crown and 1 part peels/pomace was found very ideal to achieve moisture content of 65–70 % and produced a good quality silage with minimum fungal count (<3–4 colony forming units) on 15th day of ensiling. Nutritive value in terms of energy and minerals was superior to maize green fodder. Feeding trial in two groups of sheep with 10 numbers in each group fed total mixed ration (TMR) comprising 62 % PFR/maize silage and 48 % concentrate mixture (DM basis) for 75-day period did not show any adverse effects on nutrient utilization (DM, CP, NDF, ADF), serum biochemical (total protein, creatinine, urea nitrogen, SGOT, SGPT), and mineral profile (Ca, P, Mg, Cu, Zn, Mn) and supported a daily growth rate of 140 g. The overall performance was similar to those sheep fed TMR with maize green fodder silage. Feeding PFR silage replacing hybrid napier green fodder in two groups of cows with eight in each group showed an improvement in average daily milk yield by 3.0 lit per cow and fat content by 0.6 U fed PFR silage-based TMR as compared to cows fed hybrid napier green fodder-based TMR. In both studies (sheep or cows), there was no evidence of metabolic or health-related disorders indicating that PFR silage was effectively utilized. Pineapple fruit residue that was hitherto wasted was successfully converted to silage and was found to be a valuable alternative to conventional green fodder. Ensiling of PFR not only improved the economics of feeding but also helped in overcoming the disposal problem.

Keywords Dairy cattle · Lactation · Pineapple fruit residue · Sheep · Silage

N. K. S. Gowda (✉) · N. C. Vallesha · V. B. Awachat · S. Anandan · D. T. Pal · C. S. Prasad
Division of Animal Nutrition, National Institute of Animal Nutrition and Physiology, Bangalore 560 030, India
e-mail: nksgowda@rediffmail.com

Introduction

Pineapple (*Ananas comosus*) is a commercial horticultural crop grown in some regions of India, East Asia, and Africa. In India, this crop is grown in about 90,000 ha of land, and about 35 % fresh fruit is processed in industries for juice, jam, and canned products for human consumption. Out of the whole fruit, about 65 % is nonedible that includes spent pulp, peels, crown with leaves, and pomace and hence represents substantial residual biomass (Upadhyay et al. 2010). In India, an estimated quantity of 1.3 million tones of pineapple fruit residue (PFR) is available annually and has no well-documented usage except as a waste. Due to high moisture and sugar content, the keeping quality of PFR is low resulting in putrefaction. This residue is a serious problem for disposal and also is an environmental safety issue. There are few reports suggesting the use of PFR in livestock feeding (Das et al. 2013), but complete studies on assessing the nutritive value, improving the keeping quality and livestock performance fed on PFR, are lacking. Hence, the present investigation was

undertaken to develop an effective technique to preserve PFR and examine the possibility of using PFR in livestock feeding as a novel feed resource.

Materials and methods

Sample collection and preservation

The pineapple residues (crown, peels, and pomace) from processing factories were collected. In order to preserve the PFR from putrefaction, silage making protocol was modified and standardized at laboratory scale in 2-kg plastic bottles. Crown and peels of PFR were cut and crushed into smaller pieces of 1–1.5″, and the mixture of leafy crown and peels in different proportions was compacted in plastic bottles to remove oxygen and sealed air tightly. The bottles were opened at 5-day intervals until 30 days of ensiling, and samples of the material in bottles were analyzed for pH, lactic acid content (Barker and Summerson 1941), and fungal count and observed for smell and color. This protocol was adopted and upscaled to produce bulk quantity of silage in plastic drums of 100-kg capacity.

Nutritive value analysis

The silage prepared from PFR was evaluated for nutritional composition. The dried (70 °C for 3 days) sample of PFR silage ground to a size of 1 mm in duplicate was analyzed for crude protein (CP) (AOAC 1990) and fiber fractions (neutral detergent fiber (NDF), acid detergent fiber, (ADF) and lignin (Goering and Van Soest 1970). In vitro digestibility and metabolizable energy (ME) contents were estimated by in vitro gas production technique (Menke and Steingass 1988). PFR silage was analyzed for IVOMD and ME using near infrared spectroscopy (NIRS), and software package WinISI II (FOSS, Denmark, Model NIRS™ 5000) calibrated against conventional wet laboratory analyses. The silage sample was ground to pass 1-mm mesh and scanned. NIRS equations for the silage analysis were used based on the mixed feed local calibration model, in which the chemometrics model gives more than 95 % of the confidence limits agreement.

The ground sample of dried PFR silage in duplicate was subjected to dry ashing in muffle furnace for preparation of mineral extract (AOAC 1990). The mineral extract was analyzed for calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), cobalt (Co), manganese (Mn), iron (Fe), and chromium (Cr) in atomic absorption spectrophotometer (PerkinElmer AA 300 USA) following prescribed protocol. Phosphorus (P) was estimated colorimetrically by the molybdovanadate method (AOAC 1975). Specific mineral standards (SD fineChem Ltd.) were used for each analysis to validate the findings.

Feeding trial in lambs

The study was conducted in an organized sheep farm (Anur, Chikkaballapur district). Twenty Rambouillet female lambs, 4 months of age and uniform body size, were selected and divided randomly into two groups of 10 individuals each were allocated to two groups of 10 each in completely randomized design. They were vaccinated for common infectious diseases and were dewormed before the experimental feeding. The sheep were housed in pens in a well-ventilated barn with individual feeding. Fresh water was offered ad libitum. Two total mixed rations (TMR) comprising either 62 % PFR silage (G I) or maize green fodder silage (G II) with 38 % compound concentrate feed (maize 30 %, soybean meal 45 %, wheat bran 22 %, sodium bicarbonate 0.50 %, mineral mixture 2 %, and common salt 0.5 %) were prepared (crude protein 14 %, total digestible nutrients 62 %) and offered to respective groups. They were fed either of these TMR for 75-day period to meet the nutrient requirements as per ICAR (2013a). Daily feed (DM) intake and initial and final body weights were recorded during 75 days of experimental feeding.

Nutrient digestibility

A digestibility trial was conducted during the last fortnight by the 24-h total collection method for 6 days using specially designed fecal bags with 2 days of adaptation. Total fecal void in 24 h was weighed, and a suitable aliquot was dried at 100± 3 °C overnight and dry matter (DM) was estimated. An aliquot of 1/20th from the daily total fecal output was acidified with two drops of 1:4 sulfuric acid and dried for 3 days at 60 °C for the estimation of CP. The samples of feed offered and refusal if any were also dried at 100±3 °C overnight and dry matter (DM) was estimated. The pooled dried samples of feces, feed offered, and feed residues were ground to a fineness of 1 mm and analyzed for CP, ether extract (EE), NDF, and ADF.

Blood biochemical profile

During the last week of experimental feeding, blood was collected from the jugular vein in heparinized tubes from all the sheep. Blood hemoglobin was immediately estimated by the acid hematin method. The plasma was separated by centrifugation at 7840×g for 10 min and preserved at −20 °C until analyzed for total protein, urea, creatinine, serum glutamate oxalo acetate transaminase (SGOT), and serum glutamate pyruvate transaminase (SGPT) using Span clinical diagnostic kits. Ca, Mg, Cu, Zn, and Mn in plasma were determined by atomic absorption spectrophotometry and P by colorimetry (Fiske and Subbarow 1925).

Feeding trial in dairy cows

The study was conducted in an organized dairy farm (Neernalli, Uttara Kannada district). Sixteen individual cross-bred dairy cows (HF cross) of uniform parity and milk yield were grouped into two of eight each in completely randomized design. The feeding consisted of chaffed hybrid napier green fodder or PFR silage, compound concentrate feed (maize 40 %, groundnut meal 15 %, cottonseed meal 20 %, rice bran 22 %, mineral mixture 2 % and common salt 1 %), and chaffed maize dry fodder in the ratio of 25:60:15 of the total DM requirement respectively to meet the protein and energy requirements (ICAR 2013b). The feeding trial was conducted for 90-day period and daily milk yield, fortnightly milk fat, and solids not fat (SNF) were recorded (ISI 1961). All the norms of animal ethics and welfare for conducting experiment were followed, and the experimental protocols were approved by the Institutional Animal Ethics Committee.

Statistical analysis

The data were subjected to analysis of variance in one-way classification using completely randomized design using SPSS 11.0 package as per Snedecor and Cochran (1994).

Results and discussion

Nutritive value of PFR silage

Proportion of 4 parts of leafy crown and 1 part of peels with pomace was found very ideal to achieve a moisture content of 65–70 % and produced a very good silage. The fungal count on the 15th day of ensiling was minimum (<3–4 colony forming units) and contained 6–7 % lactic acid (DM basis), indicating that the silage quality is very good. The PFR silage prepared in 100-kg capacity plastic drums also showed similar results and was highly palatable to cattle and sheep. The analysis of pineapple fruit residue silage showed that it contained on DM basis of 7.50 % crude protein, 56.04 % neutral detergent fiber, 19.76 % acid detergent fiber, 2.33 % ash, 1.26 % lignin, 0.60 % calcium, 0.30 % phosphorus, 0.17 % magnesium, 19 ppm copper, 225 ppm iron, 150 ppm manganese, 250 ppm zinc, and 15 ppm chromium. The in vitro organic matter digestibility and metabolizable energy (ME) values were estimated as 72.01 % and 10.79 MJ/kg DM, respectively. The energy value in terms of ME was exceptionally higher (equivalent to 72 % TDN), which may be due to higher sugar content and less lignin. Except for higher energy value, the nutritive value of PFR silage was comparable to maize green fodder. Values of 4–8 % crude protein, 60–72 % NDF, and 40–55 % soluble sugar in pineapple fruit residue have been reported (Wadhwa and Bakshi 2013). Fresh pineapple waste can be preserved either by drying or ensiling, and the composition on DM basis was 4–8 % CP, 60–72 % NDF, and 40–75 % soluble sugars with organic matter digestibility of 75 % and can replace the roughage component and partly the cereals in ruminant diet (Sruamisri 2007). In China, pineapple waste from the cannery industry is being used as dairy feed (Upadhyay et al. 2010). Other fruit residues like apple pomace, mango fruit waste, banana peels, and citrus by-products also have a similar nutritive value in terms of protein and energy value and have been recommended for feeding (Das et al. 2013).

Performance of sheep

There was nonsignificant difference in daily DM intake (1.10–1.20 kg per lamb). This supported daily gain of 140 g per lamb as against the targeted daily gain of 150 g. Though the nutritive value, specifically ME of PFR silage, was better than maize silage, the growth rate was similar in both the groups (Table 1). The nutrient utilization in terms of digestibilities of DM, OM, EE, NDF, and ADF was also similar in both the groups (Table 1). The higher DM digestibility of 74–75 % in both the groups is attributed to the use of concentrate mixture and fodder in the form of total mixed ration, which has a complementary and supplementary role in synchronizing the nutrient utilization in rumen (Girdhar and Balaraman 2003). Apparent digestibility of nutrients in Thai native cattle fed ensiled pineapple waste as roughage source was higher ($P<0.05$) than in cattle fed pangola hay due to shorter fibrous particles in pineapple waste and being more digestible (Suksathit et al. 2011). The above findings also confirm that feeding of silage did not exert a negative effect on rumen microbial activity as has been reported by Sniffen and Robinson (1987). The blood biochemical parameters (hemoglobin, total protein, urea, creatinine, SGOT, SGPT) and mineral profile also did not differ significantly between the groups of lambs fed either maize or PFR silage as fodder source, and the values were within the physiological range (Table 1), suggesting that feeding of PFR silage did not have any adverse effect on general health of lambs. Pineapple fruit product is known to contain higher amount of phenolic antioxidants which have health-promoting benefits (Ma et al. 2007), and increased growth rate was observed in goats fed dehydrated pineapple by-product for 80 days (Costa et al. 2007). On contrary, some researchers have reported that by-product of pineapple processing industry is not an attractive feed due to high fiber content and soluble sugars with low protein content (Correia et al. 2004). This suggests that proper nutrient balancing using other feed ingredients is required in the form of total mixed ration, as did in the present experiment.

Table 1 Performance and biochemical profile in lambs

Parameter	Group		
	I	II	Pooled SE
Feed intake and growth performance			
Average DM intake (kg/lamb/day)	1.10	1.20	0.08
Initial body weight (kg)	25.7	25.8	0.36
Final body weight (kg)	50.5	50.9	0.61
Average daily gain (g/lamb)	142	143	6.99
Feed conversion ratio	7.74	8.39	0.50
Feed cost per kg gain (Rs)	106.8	80.96	6.23
Nutrient utilization			
Dry matter digestibility (%)	74.1	75.8	1.10
Organic matter digestibility (%)	76.6	78.3	0.71
Crude protein digestibility (%)	81.6	82.8	0.65
Ether extract digestibility (%)	85.0	85.7	0.71
Neutral detergent digestibility (%)	65.4	66.1	0.62
Acid detergent digestibility (%)	55.0	56.1	0.81
Biochemical profile			
Hemoglobin (g%)	13.7	13.8	0.71
Total protein (g%)	6.24	6.51	0.41
Blood urea nitrogen (mg%)	32.9	29.2	2.10
Creatinine (mg%)	1.20	1.30	0.06
SGOT (IU/L)	147	139	12.36
SGPT (IU/L)	24.4	19.5	3.10
Mineral profile			
Calcium (mg%)	10.5	10.3	0.66
Phosphorus (mg%)	4.90	4.81	0.43
Magnesium (mg%)	2.21	2.10	0.16
Copper (ppm)	0.66	0.71	0.03
Zinc (ppm)	1.62	1.74	0.12
Manganese (ppm)	0.26	0.22	0.03

Group I maize silage, *Group II* PFR silage, *SGOT* serum glutamate oxaloacetate transaminase, *SGPT* serum glutamate pyruvate transaminase

Performance of dairy cattle

During the 90 days of feeding trial, there was a significant improvement in average milk yield by 3.0 l per cow per day (4 % fat corrected milk) or milk fat content by 0.6 U in cows fed PFR silage-based TMR as compared to cows fed hybrid napier green fodder-based TMR (Table 2). No evidence of metabolic or health-related disorders (rumen acidosis, laminitis) was noticed indicating that PFR silage was effectively utilized by the cows. The higher milk yield and fat content in cows fed PFR silage can be attributed to higher soluble sugars in PFR and better rumen microbial protein synthesis than the cows fed hybrid napier fodder, suggesting that PFR silage can be a valuable alternative to conventional green fodder. Similar results indicating better utilization of pineapple fruit residue in dairy cattle have been reported by Das et al.

Table 2 Lactation performance of cows fed PFR silage

Parameter	Group		
	I	II	Pooled SE
Average DM intake (kg/cow/day)	12.90	12.99	0.78
Average initial milk yield (Lit/cow/day) 0 day	13.5	13.5	0.81
Total average milk yield (Lit/cow/day) 1–90 days	13.2^{b}	16.3^{a}	1.10
Average initial milk fat (%) 0 day	4.0	4.0	0.10
Average milk fat (%) 1–90 days	4.1^{b}	4.7^{a}	0.08
Average initial milk SNF (%) 0 day	8.5	8.6	0.04
Average milk SNF (%) 1–90 day	8.6	8.6	0.86

Means with different superscript letters in a column differ significantly $P<0.05$

Group I maize silage, *Group II* PFR silage, *Group I* hybrid napier green fodder, *Group II* PFR silage, *SNF* solid-not fat

(2013). In China, pineapple waste from the cannery industry is being used as dairy feed (Upadhyay et al. 2010).

Cost economics

In the sheep feeding experiment, the cost of maize silage, PFR silage, and concentrate mixture was calculated to be Rs. 10, 3.3, and 20/kg DM, respectively. While accounting the cost of feed (TMR) and feed conversion ratio (FCR) in both GI and GII, the total cost of feeding per kilogram weight gain was Rs. 106.8 and Rs. 80.96, respectively, with a net saving of Rs. 25.83 in group fed PFR silage (1 USD=60 Indian Rupees).

In the dairy cattle feeding experiment, the cost of hybrid napier green fodder, PFR silage, concentrate mixture, and maize dry fodder was calculated to be Rs. 8.3, 3.3, 20, and 3/kg DM, respectively. On calculating the daily total feed intake, the cost of feeding was Rs. 203.28 and Rs. 185.78 per cow per day in GI and GII with a saving of Rs. 17.50 in PFR silage fed group. Due to higher milk yield of 3.1 lit in cows fed PFR silage, there was an additional revenue of Rs. 74.4 per cow per day. Thus, the net profit due to use of PFR silage as green fodder source was Rs. 91.9 per cow per day.

Conclusion

The results of this study suggest that silage making is an effective and practical method to preserve Pineapple fruit residue and feeding of this silage for livestock in the form of total mixed ration along with other feed/fodder ingredients

supported desired growth rate in lambs and improved lactation performance in cows and did not have any adverse effects on nutrient utilization and general health. It is concluded that pineapple fruit residue silage is a valuable local resource alternative to conventional green fodder for livestock feeding.

Acknowledgments The financial support of the National Bank for Agriculture and Rural Development (NABARD), Bangalore, and help of Director, NIANP in conducting this study is thankfully acknowledged.

Conflict of interest There is no conflict of interest among the authors and the funding agency involved in this study.

References

A O A C., 1975. Feed total phosphorous estimation by photometric method. Official methods of analysis, 12th ed. Association of Official Analytical Chemists, Washington, D.C.

A O A C., 1990. Official Methods of Analysis. 15th edn. Association of Official Analytical Chemists, Washington D C.

Barker, S. B., Summerson, W.H., 1941. The colorimetric determination of lactic acid in biological material. Journal of Biological Chemistry, 138, 535–554.

Correia, R.T.P., McCue, P., Magalhaes, M.M.A., Macedo, G.R. and Shetty, K. 2004. Production of phenolic antioxidants by the solid state bioconversion of pineapple waste mixed with flour using Rhizopus oligosporus. Process Biochemistry, 39, 2167-2172.

Costa, R.G., Correia, M.X.C., Da Silva, J.H.V., De Medeiros, A.N. and De Carvalho, F.F.R. 2007. Effect of different levels of dehydrated pineapple by-products on intake, digestibility and performance of growing goats. Small Ruminant Research, 77, 138-143.

Das, L.K., Vijaykumar., Mahesh, M.S., Dinesh Kumar., Rai, S.N., 2013. Fruit processing wastes: a potential non-conventional feed resource for dairy animals. Feed Trend, 2(3), 9-26.

Fiske, C.H., Subbarow, Y. 1925. The colorimetric determination of phosphorus. Journal of Biological Chemistry, 66, 375–378.

Girdhar, N., Balaraman, N., 2003. TMR feeding system in dairy cattle- a review. Indian Journal of Dairy Sciences, 56(4), 187-196.

Goering, H. K., Van Soest, P. J., 1970. Forage fiber analysis. U.S.D.A. Agricultural Handbook, Washington, D.C. No. 379.

I C A R., 2013a. Nutrient requirements of cattle and buffalo, No. 1, Published by ICAR, New Delhi.

I C A R., 2013b. Nutrient requirements of sheep, goat and rabbit, No. 2, Published by ICAR, New Delhi.

I S I., 1961. Methods of test for dairy industry, Part I. Chemical Analysis of milk. Indian Standards Institution, New Delhi, India.

Ma, C., Xiao, S., Li, Z., Wang, W. and Du, L. 2007. Characterisation of active phenolic components in the ethanolic extract of *Ananas comosus* L. Leaves using high performance liquid chromatography with diode array detection and tandem mass spectrometry. Journal of Chromatography A, 1165, 39-44.

Menke, K.H., Steingass, H., 1988. Estimation of the digestibility and metabolizable energy content of ruminant feedstuffs from the gas production when they are incubated with rumen liquor *in vitro*. Animal Research and Development, 28, 7-55.

Snedecor, G.W., Cochran, W.G., 1994. Statistical Methods, 8th ed, East West Press Pvt. Ltd., New Delhi, India.

Sniffen, C.J. and Robinson, P.H., 1987. Microbial growth and flow as influenced by dietary manipulations. Journal of Dairy Science, 70, 425-441.

Sruamisri, S., 2007. Agricultural wastes as dairy feed in Chiang Mai. Animal Science Journal, 78,335-341.

Suksathit, S., Wachirapakorn, C., Opatpatanakit., 2011. Effect of levels of ensiled pineapple waste and pangola hay fed as roughage sources on feed intake, nutrient digestibility and ruminal fermentation of southern Thai native cattle. Songklanakarin Journal of Science and Technology, 33(3), 281-289.

Upadhyay, A., Lamba, J.P., Tawata, S., 2010. Utilization of pineapple waste: a review. Journal of Food Science and Technology of Nepal, 6,10-17.

Wadhwa, M., Bakshi, M.P.S., 2013. Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products. RAP Publication 2013/04, FAO 2013, (Ed), H.P.S. Makkar.