Research Journal of Biological Sciences 3 (10): 1143-1146, 2008
ISSN: 1815-8846

Kinetics of Digestion and Fermentation of Apple Pomace from Juice and Puree Making

F. Kafilzadeh, G. Taasoli and A. Maleki
Department of Animal Science, Faculty of Agriculture, Razi University, Kermanshah, Iran

Abstract: This experiment was conducted to determine the differences between apple pomaces, obtained from puree and juice making. The chemical composition, rumen degradation characteristics, *in vitro* digestibility and gas production of 2 apple pomaces were determined. The dry matter (DM), neutral detergent fiber (NDF) and non fiber carbohydrates (NFC) of apple pomace from puree making and apple pomace from juice making were 185, 413.8 and 426.65 g kg^{-1} DM and 201.7, 567.9 and 281.45 g kg^{-1} DM, respectively. Apple pomace from puree making had higher soluble (43.62 vs 30.55 %) ($p<0.05$) and lower degradable (51.87 vs 67.43 %) ($p<0.05$) DM fractions. Rate of degradation was also higher in apple pomace from puree making (0.085 vs 0.05). (65.01 vs 55.01 and 63.80 vs 52.99) ($p<0.05$), respectively. Pomace obtained from puree making had higher *in vitro* DM and OM digestibility (65.01 vs 55.01 and 63.80 vs 52.99) ($p<0.05$), respectively. It is concluded that differences between apple processing (puree making or juice making) resulted in, 2 apple pomaces be very different in chemical composition (especially NFC), digestibility and rumen degradation.

Key words: Apple pomace, gas production, *in situ* digestibility, *in vitro* digestibility

INTRODUCTION

Apple pomace, a by product of juice or puree making industry, is a rich source of many nutrients including carbohydrates, minerals, except protein (Sargent, 1984). Utilization of Apple pomace in an economical and effective way would be in the interest of prevention of resource wastage and better economy of the processing plants and also reduces enviromental pollution (Huber, 1980). Production of animal feed from apple pomace is one such proposition. Apple pomace has been utilized as animal feed after ensiling (Smock and Neubert, 1950; Taasoli and Kafilzadeh, 2008) or after drying (Taasoli and Kafilzadeh, 2008). There is no information about the apple pomace from puree making and the kinetics of digestion and fermentation characteristics of it.

The objective of this study was to determine if the differences in rumen degradability, *in vitro* digestibility and gas production characteristics exsist between 2 different apple pomace (from juice making or puree making).

MATERIALS AND METHODS

Apple pomace: Apple pomace (AP) from puree making was obtained fresh from a puree making factory (Rojin Taak, Agro Industries Co. Kermanshah, Iran). The average dry matter content of fresh apple pomace was 185 g kg^{-1}. Apple pomace from juice making was obtained fresh from a juice making factory (Shahd sib processing food Co, Kermanshah, Iran). The average dry matter of this type of fresh AP was 201.7 g kg^{-1}.

Chemical composition: The chemical composition of different types of AP was determined using AOAC (1990). Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) were determined using the methods of Van Soest *et al.* (1991).

Animals and diets: Three ruminally cannulated rams weighing 45±3 kg and consuming 1.2±0.2 kg DM were used. Two weeks before starting the study, the rams were fed a diet to meet their maintenance requirements (NRC, 1985). Rams were fed a total mixedration consisting of alfalfa hay and apple pomace and barley with a ratio of forage to concentrate of 60:40 (DM basis).

***In vitro* digestibility:** Rumen fluid was collected from three rumen cannulated rams before the morning feeding. The rumen fluid was mixed on a volume basis, filtered though four layers of cheesecloth.

The incubation inoculum was prepared by diluting the fluid inoculum with the buffer (Tilly and Terry, 1963) in a 1:4 (vol/vol) ratio and stirring in a water bath at 39°C with purging CO_2 until its use (10-15 min later), 250 mg of each sample was placed into 50 mL strile tubes and 20 mL of the incubation inoculum was added. The tube was stoppered with a Bunsen valve and incubated for 48 h at 39°C. Tubes were gently swirled by hand four times every

Corresponding Author: F. Kafilzadeh, Department of Animal Science, Faculty of Agriculture, Razi University, Kermanshah, Iran

8 h; each sample was incubated in three replicates. At the end of the 48 h incubation period, tube contents were acidified by adding 6 M HCL to reach a final pH of 1.3- 1.5. After a few seconds, when the foam subsided, pepsin powder (EC 3.4.23.1) was added to a final concentration of 0.2% (wt/vol). The tubes were reincubated for an additional 48 h. The tubes were centrifuged at 2500 rpm for 15 min and the supernatant was discarded. The tubes containing the pellets were dried in a forced air oven at 55°C for 48 h to determine the residual DM weights. *In vitro* dry matter and organic matter digestibility was calculated, respectively as the DM and OM which disappeared from the initial weight inserted into the tube.

***In vitro* gas production:** The method used for gas production measurements was as described by Theodorou *et al*. (1994). All samples were ground to pass a 0.2 mm screen. About 150 mg of each sample were weighed into tubes kept at approximately 39°C and flushed with CO_2 before use. Each sample was incubated in three replicates. Fifteen ml of buffered rumen fluid (in the proportion of 20% rumen fluid + 80% medium) prepared (as described in the *in vitro* digestibility section) and were anaerobically dispensed in each tube at 39°C. All the tubes were crimped, placed in the incubator at 39°C and shaken at regular times. The pressure of gas produced in each tube was recorded using a pressure transducer (testo 512) at 2, 4, 6, 8, 8, 12, 18, 24, 48, 72 and 96 h after start of the incubation (Theodorou *et al*., 1994). Cumulative gas production data were fitted to exponential models (Ørskov and McDonald, 1979) to estimate kinetic parameters as:

Y = b (1 – $\exp^{-ct}$).
b = Potential of gas production.
c = Gas production rate constant for the insoluble fraction.
t = Incubation time (h).
y = gas (t).

***In situ* studies:** A standard procedure for small nylon bags was used to estimate ruminal disappearance of DM (Ørskov *et al*., 1980). All the samples were ground to pass a 2 mm screen. Approximately 1.5 g (air dry) of samples were weighed into 5 cm ×12 cm nylon bags (porosity = 45 μm) for each sample and incubation time (0, 1, 2, 3, 4, 6, 8, 12, 24 and 48 h). Each sample was replicated two times. Upon removal from the rumen, nylon bags were immediately rinsed under tap water until the effluent was clear and then dried at 55°C for 48 h. Percentage disappearance of DM at each incubation time was calculated from the proportion remaining in the bag after incubation in the rumen. The disappearance rate was fitted to the following equation given by Ørskov and McDonald (1979):

$$\text{Disappearance (\%)} = a + b(1-e^{-ct})$$

where, a is the soluble fraction (% of total), b the degradable fraction (% of total), t the time of incubation (h) and c is the rate of degradation. The effective degradability of DM was calculated by the equation of Ørskov and McDonald (1979):

$$\text{EDMD (\%)} = a + b\,(c / c + k)$$

where, k is the estimated rate of outflow from the rumen and a, b and c are as defined in the disappearance equation.

The data was analyzed using the fitcurve programe. All statistical analysis was done using the SPSS (2002) procedure.

RESULTS AND DISCUSSION

Chemical composition of the two different apple pomaces are shown in Table 1.

***In vitro* digestibility:** The results of in vitro DM and OM digestibility are shown in Table 1. Apple pomace from puree making had the higher *in vitro* DM and OM digestibility. Higher digestibility of DM and OM in the pomace from puree making was associated with higher NFC content and lower NDF compare with apple pomace from juice making.

***In situ* degradability:** Table 2 shows the results of dry matter degradability parameters of two different apple pomaces. Apple pomace from puree making had the higher soluble fraction (a) of DM (about 42% higher than apple pomace from juice making). Higher NFC content of apple pomace from puree making (about 51 %) resulted in higher a fraction than apple pomace from juice making. The insoluble but fermentable component (b fraction) in AP from juice making was significantly more than that in AP from puree making. This degradable fraction reflects the proportion of DM that is degraded in the rumen at a measurable rate. This fraction is nutritionally important because it provides the major source of slowly fermenting carbohydrates for rumen microbes. Apple pomace from puree making had higher rate of degradability (c). The effective Dry Matter degradability of apple pomace from puree making was significantly ($p<0.05$) higher than that in apple pomace from juice making. Pirmohammadi *et al*.

Table 1: Chemical composition (g kg^{-1} DM) and *in vitro* digestibility (%) of apple pomaces from puree and juice making

	Apple pomace from :			
Items	Juice making	Puree making	SEM	Sig.
DM	201.7	185		
OM	974.8	962.2		
ASH	25.2	37.8		
CP	58.85	56.75		
NDF	567.9	413.8		
ADF	419.2	315.3		
EE	57.6	65		
NFC	281.45	426.65		
In vitro digestibility (%):				
DM	55.02	65.01	2.49	0.015
OM	53.99	63.80	2.46	0.020

DM: Dry Matter, OM: , Organic matter, CP: Crude Protein, NDF: Neutral Detegent Fiber, ADF: Acid Detegent Fiber, EE: Ether Extract, NFC: Non Fiber Carbohydrates. NFC = 100- (%NDF+ %CP+ %Fat+ %ASH). SEM: standard errors of means

Table 2: Dry matter degradability parameters (a, b and c) and estimated effective degradability of DM at different outflow rates of two different apple pomaces produced from juice and puree making

	Apple pomace from:			
Degradability parameters	Puree making	Juice making	SEM	Sig.
a (%)	43.62	30.55	2.96	0.01
b (%)	51.87	67.43	3.50	0.009
c (f/h)	0.08	0.05	0.065	0.009
a+b	95.49	97.98	1.32	0.38
Estimated effective degradability of DM at different rumen outflow rates (% h^{-1}):				
0.05	80	65	3.1	0.002
0.08	72	57	3.8	0.032

a: rapidly degraded fraction (%); b :slowly degraded fraction (%); c: rate of degradability (fraction/h) ; SEM: standard errors of means

Table 3: Gas production parameters (b and c) and estimated effective degradability of DM at different outflow rates of two different apple pomaces produced from juice and puree making

	Apple pomace from:			
Gas production parameters	Puree making	Juice making	SEM	Sig.
b (%)	53.23	77.56	6.06	0.015
c(f/h)	0.0370	0.0275	.002	0.048
Estimated effective degradability of DM at different rumen outflow rates (% h^{-1}):				
0.05	31.97	36.83	1.25	0.024
0.08	26.23	29.17	0.79	0.043

b :potential gas production (%); c: rate of gas production (fraction/h); SEM: standard errors of means

(2005) reported the values of 38.5 and 51.3% , 27.3 and 52.9% for a and b fraction for dried and ensiled AP, respectively. Anrique and Viveros (2002) observed that the mean values for DM soluble (a), slowly degradable (b) fractions and total degradability (a+b) of ensiled AP were 13.8, 75.7 and 89.5%, respectively. The degradabilities of AP from puree and juice making in the present study was 95.49 and 97.98%, respectively (Fig. 1).

***In vitro* gas production:** Table 3 shows the results of gas production parameters. Gas production is basically the result of the fermentation of carbohydrates into acetate, propionate and butyrate (Gatachew *et al*., 1998). Higher rates of gas production (c) observed in AP from puree making, possibly influenced by the soluble carbohydrates fraction (a) readily availability to microbial population. Apple pomace from juice making had higher b fraction than AP from puree making, although, the rate at which gas was produced in AP from puree making was significantly ($p<0.05$) higher than AP from juice making. Gas production rate in apple pomace from puree making was higher (about 35%) than that in apple pomace from juice making.

Table 4: Correlation between *in situ* and *in vitro* gas production parameters.

Parameters	Correlation	Sig.
a_{gas} and a_{insitu}	0.52	0.28
b_{gas} and b_{insitu}	-0.12	0.82
c_{gas} and c_{insitu}	0.42	0.42
$a + b_{gas}$ and $a + b_{insitu}$	-0.32	0.53

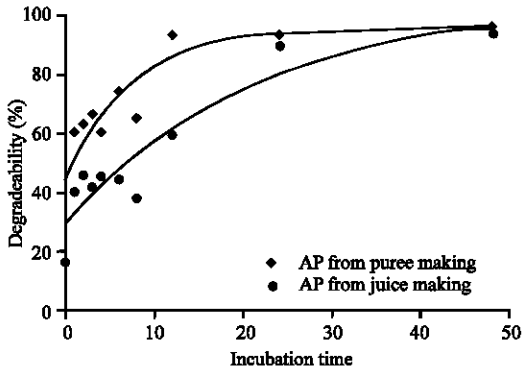

Fig. 1: The degradability of two different apple pomaces

So, b fractions of DM degradability (*in situ*) and gas ptoducion of apple pomace from juice making were significantly higher than b fraction of apple pomace from puree making.

As it is shown in Table 4, there was no significant correlation between a_{gas} and a_{insitu}, b_{gas} and b_{insitu}, c_{gas} and c_{insitu}, $a + b_{gas}$ and $a + b_{insitu}$. The results obtained in this experiment are in agreement with those reported by Khazaal *et al*. (1993), Blummel and Ørskov (1993) and Sileshi *et al*. (1996), who observed a correlation between DM disappearance and gas production but they did not find a significant correlation between the rate of DM degradation (c_{insitu}) and rate of gas production (c_{gas}), which was in agreement with present findings.

CONCLUSION

The AP from puree making had higher digestibility than the AP from juice making. Such differences are due to the effect of different processing used in puree and juice making. Higher NFC content of apple pomace from

puree making resulted in more readily fermentable fraction in this by-product compared to apple pomace produced from juice making. Further studies on the nitrogen and carbohydrate degradability kinetics may prove useful in further determining and comparing the feed value of these two types of apple pomaces.

REFERENCES

Anrique, R. and P.M. Viveros, 2002. Effect of ensiling on chemical composition and rumen degradability of apple pomace. Arch. Med. Vet., 34 (2): 189-197.

AOAC, 1990. Official Methods of Analysis. 15th Edn. Association of Official Analytical Chemists, Arlington, USA.

Blummel, M. and E.R. Ørskov, 1993. Comparison of *in vitro* gas production and nylon bag degradability of roughages in predicting of food intake in cattle. Anim. Feed. Sci. Technol., 40: 109-119.

Gatachew, G., M. Blummel, H.P.S. Makkar and K. Becker, 1998. *In vitro* gas measuring techniques for assessment of nutritional quality of feeds: A review.Anim. Feed Sci. Technol., 72: 261-281.

Huber, T.T., 1980. Upgrading Residual and byproducts for animals. Boca Raton, Fla, CRC Press.

Khazaal, K., X. Markantonatos, A. Nastis and E.R. Ørskov, 1993. Changes with maturity in fiber composition and levels of extractable polyphenols in Greek browse: Effect *in vitro* gas production and in sacco dry matter degradation. J. Sci. Food Agric., 63: 237-244.

NRC, 1985. National Research Council, 1985. Nutrient Requirments of sheep, 6th Rev. National Academy Press, Washington, DC.

Ørskov, E.R. and McDonald, 1979. The estimation of protein degradability in the rumen from incubation measurements weighed according to rate of passage. J. Agric. Sci. (Camb.), 92: 499-503.

Ørskov, E.R., F.D. Hovell and F.D.Mould, 1980. The nylon bag technique for nutritional studies in ruminants. Trop. Anim. Prod., 5: 195-205.

Pirmohammadi, R., Y. Rouzbehan., K. Rezayazdi and M. Zahedifar, 2006. Chemical composition, digestibility and *in situ* degradability of dried and ensiled apple pomace and maize silage. J. Small Rumin. Res., 66: 150-155.

Sargent, S.A., 1984. An energy and cost analysis model to evaluate the combustion of food processing wastes. Ph.D. Thesis, Department of Agriculture Engineering, Michigan State University, E. Lansing.

Sileshi, Z., E. Owen, M.S. Dhanona and M.K. Theodorou, 1996. Prediction of *in situ* rumen dry matter disappearance of Ethiopian forages from an *in vitro* gas production technique using a pressure transducer, chemical analyses or *in vitro* digestibility. Anim. Feed Sci. Technol., 61: 73-87.

Smock, R.M. and A.M. Neubert, 1950. Apple and Apple Products. Interscience. Publishers, New York.

SPSS (Statistical Package for Social Sciences), 2002. User's guide. Version 11.5. spss Inc. Chicago, IL. USA.

Taasoli, G. and F. Kafilzadeh, 2008. Effects of dried and ensiled Apple pomace from puree making on performance of finishing lambs. Pak. J. Biol. Sci., 11 (2): 294-297.

Theodorou, M.K., B.A. Williams, M.S. Dhanoa, A.B. McAllan and J. France, 1994. A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds. Anim. Feed Sci. Technol., 48: 185-197.

Tilly, J.M.A. and R.A.Terry, 1963. A two stage technique for all *in vitro* digestion of forage crops. J. Br. Grassland Soc., 18: 104-111.

Van Soest, P.J., J.B. Robertson and B.A. Lewis, 1991. Methods of dietary fiber, neutral dtergent fiber and non-starch polysaccharide in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.