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| Title | 沖縄肉用山羊の生産,第一胃内性状及びその肉質に及ぼす飼料の影響 : I. 第一胃内性状に与える青苅り野草の影響(畜産学科) |
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# Study on Okinawan Meat Goat Production and Meat Quality as Influenced by Diets

## I. Effect of Green Grasses on Rumen Characteristics

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### Summary

Four fistulated crossbred Okinawan meat goats were fed (1) green grasses consisting of Paragrass, Napiergrass, Tachiawa Sendangusa and Noasagawo, (2) alfalfa hay cube (70%) + concentrate (30%, in the form of pellet) and (3) alfalfa hay cube to study their effects on physio-nutritional characteristics such as rumen pH, temperature, numbers of bacteria and protozoa and VFA production.

When dry matter intake was limited to 2.5% of body weight acording to the NRC feeding standard, consumption of DCP in green grass fed goats was depressed as well as TDN and DE due to bulkiness of this diet. This seems to be the main factor attributable to the reported slower growth rate of meat goats fed green grasses only compared to those fed rations with concentrates. Rumen temperature was significantly lower in the goats fed green forage diet at each sampling time than those fed cube, and cube plus concentrate diets with no difference between the latter two diets. Compared to other two diets, feeding of alfalfa cube diet with concentrate resulted in lower pH with higher values in criteria such as numbers of live rumen bacteria, total protozoa, Spirotrichida, Entodiniums and concentrations of total VFA, acetic, propionic, butyric and n-valeric acids. Green grass fed goats, on the other hand, had intermediate figures in the number of Entodinium with tail and the highest value in Ophryoscolex, but were lowest in the concentrations of total VFA, acetic and n-valeric acids. Concerning with the proportion of individual VFA production, goats fed PC diet showed the highest fluctuation pattern in butyric acid. Contrary to our expectations, goats fed green grass deit gave the highest pattern in the proportion of propionic acid.

From these results, it is suggested that feeding of green grasses to Okinawan meat goats without any protein or energy supplementation depresses intake of


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DM, DCP and TDN due to its bulky characteristic and results in lower values determined in this experiment. Therefore, as goats fed green grasses exclusively would grow slowly and their marketing ages are delayed, "Sashimi" or sliced raw meat prepared from them becomes more tasty. In relation to offensive smell of soup prepared from goats fed ration containing concentrate, butyric acid may partly attributable as well as fatty acids from diet and those of microorganisms.

## Introduction

In 1936, approximately 155,000 goats were raised in Okinawa prefecture and in 1935 goat meat consumption made up about 25% of all livestock meat[24]. However, in recent 14 years the number decreased from 35,188 in 1975 to 17,197 in 1988. Such reduction is considered to be due to the low economical efficiency in relation to lower daily gain, feed efficiency, reproduction, higher motality of kids and deficiencies in resarch concerning their feeding and management. On the other hand, the demand for meat goats in Okinawa is very high with about 7,500 heads being imported annually from other prefectures or foreign countries[14].

Traditionally, meat goats have been raised on green grasses in Okinawa paying less attention to their feed efficiency. However, some farmers have begun to feed their meat goats rations containing concentrates to increase the daily gain and meet the demand. As a result it is pointed out that raw meat or "sashimi" and soup prepared from goat fed rations containing concerntrates is less tasty and has offensive smell, respectively, compared to those from goats fed green grasses only. Kako et al.[19] suggested that flavours resulting from cooking and heating are attributed to both volatile compounds of low boiling points, found in original raw meat and those generated on such treatment. They also pointed out that volatile fatty acids of neutral and acidic are responsible for smells of raw meats and their specific differences are attributable to the relative proportions of these two acids. Also, soup prepared from goat fed concentrates is said to be not clear due to the suspension of lipids.

Propionic acid is known to be glucogenic, while acetic and butyric are used for fat synthesis[25]. Also, long chain fatty acids resulted mainly from hydrogenation of unsaturated fatty acids by rumen bacteria and those of bacteria are also absorbed from small intestine and used for body fat synthesis. To find causes or factors attributing to the offensive smells or flavours of soup prepared from goats fed rations containing concentrates, therefore, it is necessary to distinguish the differences in ruminal changes taking place as influenced by diets.

This experiment was conducted to study the effects of green grasses on criteria such as rumen pH, temperature, populations of bacteria and protozoa, and concetration of VFA in Okinawan meat goat and to compare with those of alfalfa cube and alfalfa cube plus concentrate pellet rations.

## Experimental procedure

One year old four Okinawan meat goats of Saanen × Native, with rumen fistula and weighing 30 to 40 kg, were used as experimental animals. These animals received (1) green

grasses consisting of Paragrass (*Brachiaria mutica*), Napiergrass (*Pennisetum purpureum*), Tachiawa Sendangusa (*Bidens pilosa radiate Scherff*) and Noasagawo (*Ipomoea indica*), (2) Alfalfa hay cube (70%) plus concentrate (pellet, 30%) and (3) alfalfa hay cube. Half of the two percent of body weight on DM basis, determined according to NRC feeding standard, was fed at 0900 and 1900 hrs. Water was offered ad lib for 2 hrs after feeding. Rumen temperature was recorded by inserting an alcohol thermometer to the central part of the rumen. Rumen pH was also determined at the same place using HORIBA pH meter with an electrode. For the determination of live bacteria number, rumen content taken through fistula was filtrated with 4 layers of gauze and 1 ml of it was diluted with aerobic diluting solution prepared according to the procedure described by Bryant and Burkey[10]. This was inoculated into tubes containing RGCA medium and rolled on the rol tuber for rol tube preparation. Tubes thus prepared were incubated at 39℃ for 48 hrs and average of 5 tubes was considered as live bacteria number for each sampling time.

As for the number of rumen protozoa, 1 ml of rumen content was treated with 5 ml MFS[15] solution for fixation and staining. Then it was strained through 4 layers of gauze to separate the protozoa from plant particles. One-tenth ml of this solution was observed twice per sample under a microscope with an ocular micrometer and protozoa number was taken as the average number of 10 visual filds. They were roughly classified into some genera.

For VFA determination[21], 1 ml of 25% meta phosphoric acid was added as deproteinizer to 5 ml rumen content and centrifuged at 3,00 and 12,000 rpm for 15 minutes. Eaqual amount of crotonic acid was added to the supernatant as an internal standard substance. One $\mu$l of this mixture was injected into HITACHI gasschromatogragh (Model 073). The analytical conditions of determination were: column, 2 m×0.5 mm glass column; column packing, DGS+$H_3PO_4$ (5+1% and 60/80 mesh); column support, chromosorb WAW DMCS; column temperature, 150℃; injection and detection temperature, 200℃; carrier gas, nitrogen; flow rate, 40ml/min. Chromato-intigrator (Hitachi, model D - 2500) was used for calculation of VFA peak area. Molar proportion of rumen VFA was calculated after changing the percentage values to "Angle" (Angle=$\sqrt{\text{arcsin percentage}}$).

Table 1. Chemical composition[a]

| Item | Ingredient or diet[b] | | | | | |
|---|---|---|---|---|---|---|
| | C | P | NP | TS | NA | PR |
| DM | 85.0 | 87.0 | 23.9 | 16.1 | 20.3 | 23.3 |
| CP | 12.4 | 12.7 | 4.1 | 7.6 | 7.8 | 6.0 |
| CFt | 2.2 | 3.1 | 3.2 | 3.7 | 3.4 | 2.9 |
| CFb | 26.6 | 3.9 | 28.1 | 17.0 | 18.8 | 27.0 |
| Ash | 18.0 | 17.0 | 20.6 | 23.8 | 18.5 | 18.3 |
| NFE | 41.0 | 63.0 | 44.1 | 48.0 | 51.5 | 45.8 |
| GE, Cal/g | 4.4 | 4.4 | 4.1 | 4.2 | 4.3 | 4.3 |

[a]On dry matter basis.
[b] C: Cube; P: Pellet; NP: Napiergrass
TS: *Tachiawa Sendangusa;* NA: *Noasagao*
PR: Paragrass

Compositions of deits or ingredients were determined by conventional method. The results are shown in Table 1. Their digestibilities determined by total feces collection method are shown in Table 2.

Table 2. Digestibility of experimental diets fed to meat goat

| Item | Ingredient or diet PC | G | C |
|---|---|---|---|
| DM | 62.7 | 68.5 | 62.2 |
| CP | 80.1 | 78.9 | 81.6 |
| CFt | 39.9 | 64.4 | 58.0 |
| CFb | 35.3 | 55.7 | 50.5 |
| NFE | 67.4 | 74.4 | 72.3 |
| GE, Cal/g | 59.4 | 68.3 | 65.9 |
| DCP[a] | (10.0)7.6 | (5.0)1.0 | (10.6)9.3 |
| TDN[b] | (54.3)47.5 | (57.2)11.9 | (60.4)53.3 |

[a,b]On as fed basis. Figures in the parentheses are based on DM.

## Results and discussion

Daily requirement and consumption of nutrient of goat are presented in Table 3. Dry matter intake was limited to 2.5% of the body weight and no attempt to equalize the energy and nitrogen levels of the diets was made in order to simulate the feeding methosds traditionally practiced by the farmers here on Okinawa. Although goats in all diet groups met the requirement for DM, DCP, TDN and DE, the differences in the consumption of the former three nutrients among the treatment groups were very large. The bulkiness of the green grass diet was the main limiting factor for the reduction in the intakes of DM, TDN and especially DCP. Eventually, this appears to be attributable to the slower growth rate reported in grass fed goats compared to those fed rations containing concentrates.

Table 3. Daily nutrient requirementa and consumption of meat goat

| Item | Diet PC | G | C | Required |
|---|---|---|---|---|
| DM, g | 903.1 | 720.2 | 758.8 | 650−810 |
| DCP, g | 90.5 | 36.3 | 80.1 | 35−43 |
| TDN, g | 490.7 | 411.5 | 451.4 | 362−448 |
| DE, Mcal | 2.6 | 2.1 | 2.2 | 1.59−1.98 |
| GE, Mcal | 4.0 | 3.1 | 3.3 | |

[a]NRC: National Research Council, USA

Effects of diets on rumen temperature recorded at various sampling times are shown in Fig.1. Rumen temperatures of goats fed G diet and recorded at all sampling times except 8 hours after feeding were significantly ($P<.01$) lower than those of goats fed PC diet with no differencece between G and C diets except 8 hurs afterr feeding. Peaks of temperature were

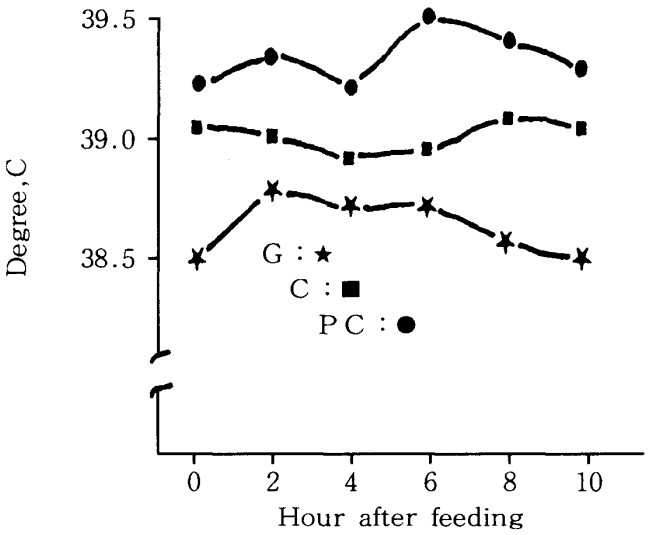


Fig.1. Temperature in the rumen of meat goat fed differnt diets.

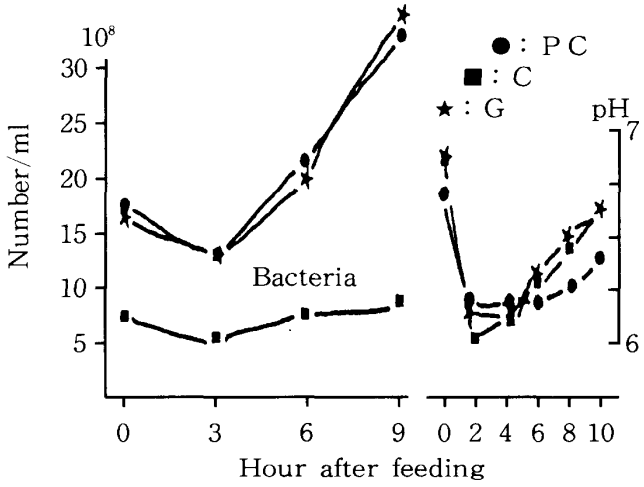


Fig.2. Effect of different diets on rumen bacteria number and pH. G: green grasses. C: alfalfa cube. PC: concent-rate pellet (30%) + alfalfa cube(70%).

observed 2 and 6 or 8 hrs after feeding. This seems to indicate that two types of microorganisms were involved in ruminal fermentation: starch and sugar fermenting organisms around 2 and cellulose fermenting organisms around 6 or 8 hrs after feeding.

Effects of diets on rumen pH are shown in Fig. 2. Rumen pH of goats fed PC diet had lower values at all sampling times except 2 and 4 hrs after feeding and the differnces at 8 and 10 hrs were significant ($P<.05$). This seems to be partly due to the fact that goats of PC diet received more DM (Table 5). Although it is well known that feeding of high concentrate diet results in rapid and significant decrease in pH[11,17], PC diet containing 30% pellet did not show such a rapidly significant reduction compared to other diets. Fluctuation patterns of pH for G and C diets were similar throughout the experiment. Value of rumen pH is said to be affected by concentrations of VFA and lactic acid. There was a significant correlation between pH and VFA ($P<.05$).

Number of live rumen bacteria as affected by diets are presented in Fig. 2. Live rumen bacteria of goats fed C diet showed significantly ($P<.05$) lower value ranging from 5.84 to $8.75\times10^8$/ml at all sampling times except 3 hrs after feeding than those fed G or PC diets with values ranging from 13.00 to $29.85\times10^8$/ml and from 13.35 to $28.20\times10^8$/ml, respectively. Addition of pellet and inclusion of 4 grasses in G diet appear to be attributable to this difference. There were no differences in the number between G and PC diets. Live rumen bacteria numbers for all diets were lowest at 3 hrs after feeding and increased rapidly in PC and C diet groups but gradually in C diet group. Reduction at 3 hr was due to mechanical dilution with water and diet intakes. From figure 2 it seems that there is a time lag between increase in bacteria numbers and reduction in pH values.

Effects of diets on total rumen protozoa and order numbers are shown in Fig. 3. Inclusion of pellet in alfalfa cube (PC) sginificantly ($P<.01$) increased total rumen protozoa number ranging from 143.3 to $172.1\times10^4$/ml compared to those of C and G diets which ranged from 68.7 to

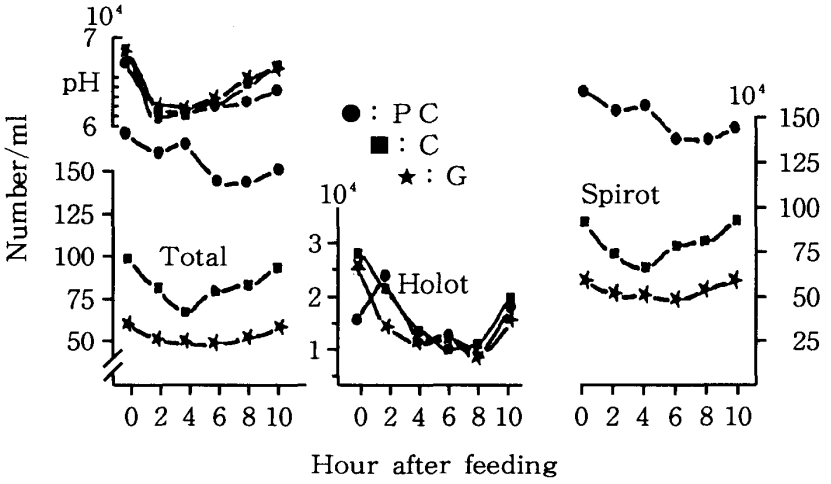


Fig.3. Rumen protozoa number as affected by feeding of different diets. Holot: holotrichchida. Spirot: spirotrichida. G: green grasses. C: alfalfa cube. PC: concentrate pellet (30%) + alfalfa cube (70%).

96.1×10⁴/mℓ and from 49.8 to 62.1×10⁴/mℓ, respectively. In G and C diet groups there were high ($P<.05$) correlation between total rumen protozoa numbers and pH values. Ito et al.[16] also have reported a correlation between these two criteria.

Concerning with Holotrichida, the numbers in all diet groups except 0 hr for PC diet decreased gradually as sampling time and increased again at 10 hrs after feeding or just prior evening feeding. This is in agreement with works reported by Dehority and purser[13] and Abe et al[3]. There were no differences among diet groups and showed similar fluctuation pattern except at 0 hr in PC diet. Purser[23] pointed out that the diurnal cycle of Holotrichs is different from that of Entodium and agreeable with that obtained by other workers and he suggested that although cycle of Entodinium is controled by physical dilution factors such as those due to feeding and salivation that of Holorichs did not appear to be the case. Abe et al.[3] reported that Holotrichida number in goat began to increase 1 hr before feeding and reached its highest value at 30 minutes after feeding and they suggested that Holotrichs sequester in the reticulum to avoid the washout by digesta pasage from the rumen to the lower digestive tracts and to maintain their population in the rumen.

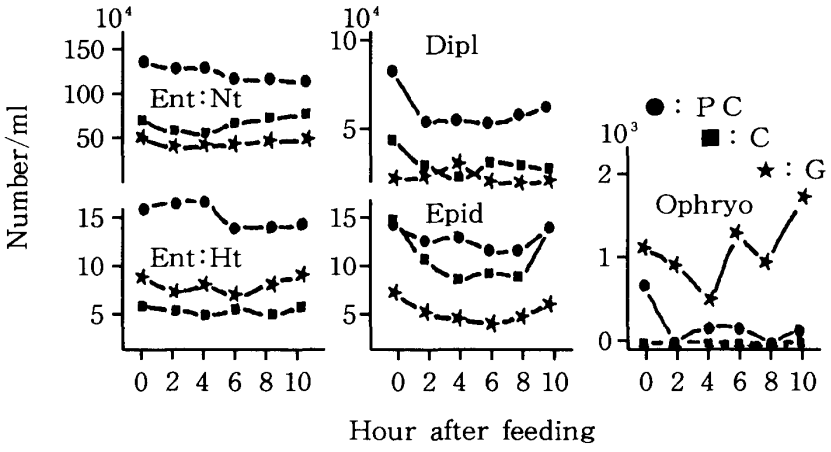


Fig.4. Effect of diets on rumen protozoa no. Ent:Nt; entodinium with no tail. Ent:Ht; entodinium having tail. Dipl: diplodinium. Epid: epidinium. Ophryo: ophryoscolex. G: green grasses. C: alfalfa cube. PC: concentrate pellet(30%) + alfalfa cube (70%).

Flactuation pattern of Spirotrichida was different from that of Holotrichida with decrease as sampling time until 4 or 6 hrs after feeding due to physical dilution effects of feed and water intakes and salivation. As the number of Holotrichida is small in the total protozoa number, the flactuation curves of Spirotrichida are very similar to those of total protozoa numbers. PC diet group had

approximately twice or three times more (P<.01) Spirotrich number throught the experiment period compared to G and C diet groups.

Effects of diets on some genus numbers are presented in Fig.4. Entodinium genus is mophologically classified into two groups: one with tails and the other with no tails. Fluctuation curves of G diet group for all genera had lower values at all sampling times except those for Ophryoscolex. The numbers of Entodinium, consisting about 30% of total protozoa, for PC diet group were significantly (P<.01) higher at all times than those for G and C diet groups. Diet high in starch content is said to result in high Entodinium number[2] and PC diet seems to be the case. Numbers of Diplodinium at all sampling times were highest in PC among three diet groups with statistical significant (P<.01) differences at 4, 8 and 10 hrs. It is considered that diets high in grains bring about an increase in this genus. The numbers in G and C diets fluctuated in similar pattern. Concerning with Epidinium, no differences were found in its numbers among diet groups except(P<.01) at 6 hrs between PC and G diets. Epidinium has been reported to be more highly dependant on concentrate diet than other genera in the Spirotrichics[8]. Being different from other genera, numbers of Ophryoscolex in G diet group fluctuated with higher values at all sampling times than those in PC and C diet groups with statistical (P<.05) differences at 2 hr. Although in PC diet group some organisms of this genus were observed, there was none in C diet group. Diets high in starch is said to promote Ophryoscolex number[25], but it seems that substances or nutrients other than satarch seem to be involved here since soluble carbohydrate content of C diet was found to be higher than that of G diet.

Concentrations of total and individual VFA as influenced by diet groups are shown in Fig. 5 and Table 4. As for total VFA, the values were low at 0 hr and reached their peaks at 2 hrs in C diet, but at 4 hrs in PC and G diet groups and gradually decreased. The values for PC diet were higher compared to other diets and the differences were significant (P<.01) at all times except 2 and 4 hrs. The values for G diet fluctuated with the lowest values, while C diet group showed intermediate fluctuation values. These differences appear to be due to less intakes of DM, DCP,

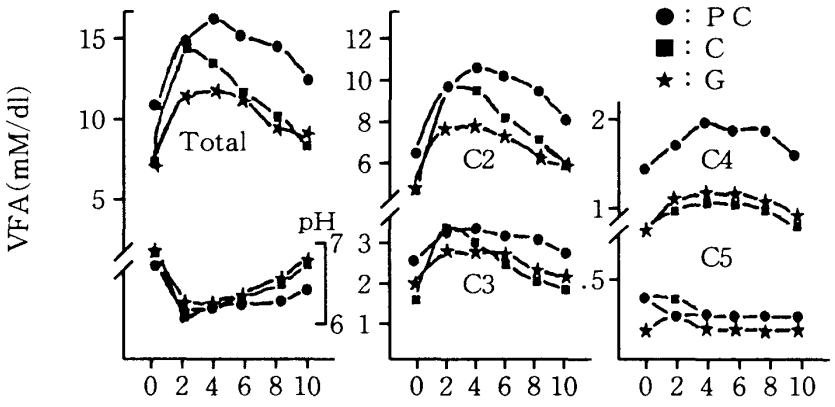


Fig.5. Rumen VFA production as affected by feeding of different diets. G: green grasses. C: alfalfa cube. PC: concentrate pellet(30%) + alfalfa cube (70%).

Table 4. Production of volatile fatty acid(VFA) in the rumen of meat goat fed different diets

| Diet | VFA mM/dl | Sampling time after feeding, hour 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|---|
| G | C2 | 4.5 | 7.6 | 7.7[b] | 7.4[b] | 6.3 | 5.8 |
| | C3 | 1.9[b] | 2.7[b] | 2.7 | 2.6 | 2.3 | 2.2[b] |
| | C4 | 0.6 | 1.0 | 1.1 | 1.1 | 0.9 | 0.8 |
| | C5 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| | Total | 7.5 | 11.5 | 11.8 | 11.4 | 9.6 | 9.0 |
| PC | C2 | 6.5[a] | 9.8[a] | 10.7[a] | 10.2[a] | 9.4[a] | 8.0[a] |
| | C3 | 2.5[a] | 3.2[ab] | 3.3[a] | 3.1[a] | 3.0[a] | 2.7[a] |
| | C4 | 1.4[a] | 1.7[a] | 2.0[a] | 1.9[a] | 1.9[a] | 1.6[a] |
| | C5 | 0.4[a] | 0.3 | 0.3[a] | 0.3[a] | 0.3[a] | 0.3[a] |
| | Total | 10.7[a] | 15.0[a] | 16.3[a] | 15.3[a] | 14.7[a] | 12.6[a] |
| C | C2 | 4.5 | 9.9[a] | 9.4[ab] | 8.1[ab] | 7.0 | 5.8 |
| | C3 | 1.5[a] | 3.3[a] | 2.9[ab] | 2.4 | 2.0 | 1.7[c] |
| | C4 | 0.6 | 0.9 | 1.0 | 1.0 | 0.9 | 0.7 |
| | C5 | 0.4[a] | 0.4[a] | 0.3[a] | 0.3[a] | 0.3[a] | 0.3[a] |
| | Total | 7.0 | 14.5[a] | 13.6[a] | 11.7 | 10.2 | 8.2 |

[a,b]Means among diets with a common superscript are not significantly different (P>.01).

TDN and DE in G diet group (see Table 5). Less total protozoa numbers in G diet group may also be attributed to these differences.

The fluctuation patterns of acetic acid were similar to those of total VFA. Acetic acid levels were higher in PC diet group at all sampling times with significantly higher (P<.01) values at 0, 8 and 10 hrs than those found in C and G diet groups. This is not agreeable with general findings[6,7,11] in which diets high in rouphage produced more acetic acid than those high in concentrate. The reasons for above result in this experiment are not clarified.

Concentrations of propionic acid in PC diet group ranged from 2.5 at 0 hr to 3.3 mM/dl at 4 hrs and were significantly higher at all sampling times than those of G diet and C except 2 and 4 hrs after feeding which ranged from 1.9 at 0 hr to 2.7 at 4 hrs and from 1.5 at 0 hr to 3.3 mM/dl at 2 hrs after feeding, respectively. The trend of diet effect on this acid production was similar to those reported so far. The highest values were observed at 2 or 4 hrs after feeding in all diet groups. G diet group showed the lowest fluctuation pattern throughout the experiment.

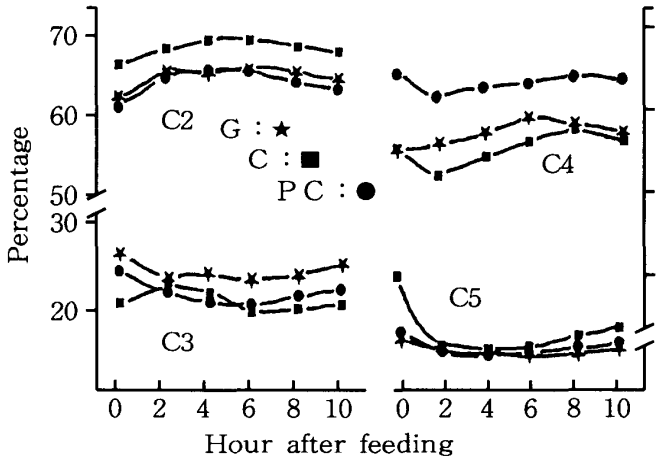


Fig.6. Molar proportion of individual VFA as affected by feeding of various diets.

Productions of butyric acid in PC diet group were consistently higher (P<.01) throughout the experiment than those in G and C diet groups. It is reported that presence of protozoa and supplementation of highly fermentative materials result in high butyric acid

production[5]. There were no differnces between G and C roughage diets. Increased production of butyric acid, therefore, seems to be one of factors contributing to the unpopularity of goat meat or goat soup prepared from goats fed diet containing concentrate.

Concentrations of n-valeric acid in G diet group were lower ($P.< 01$) at all sampling times except 2 hrs after feeding than those in C and PC diets. It seems to be due to the fact that n-valeric acid level is positively regressive to the amount of diet protein[17].

Proportions of individual VFA, influenced by diets, are shwon in Fig. 6. In all diet groups, their ratios were in order of acetic, propionic, butyric and n-valeric. Abou-Akkada and Howard[4] and Gutierrez[12] reported that a large proportion of VFA produced by protozoa was found to be acetic and butyric. This may indicate that propionic acid is mainly produced by bacteria or involvement of bacteria in the production of propionic acid is larger than that of protozoa. Concerning with acetic acid, its proportion was highest ($P<.01$) in C diet group and followed by G diet group with no differences between the latter and PC diet groups. This is in agreement with findings reported so far[6,7,11]. Contrary to our expectations, propionic acid ratios were higher in G diet group than those in C and PC diet groups although not necesarilly being statistically significant and there were no differences between C and PC diet groups. This result is not agreeable with those of previous workers[6,7,11]. The caluculated values of digestible CF/TDN for G, C and PC diets were 22.1, 22.6 and 12.4%, respectively. One of possible factors contributing to this contradictious result is different DM intakes; 720, 759 and 903 g for G, C and PC diets, respectively. As well as the absolute butyric acid levels the proportions of butyric acid in PC diet group showed higher values at all sampling times than those in G and C diet groups. The butyric acid proportions were in order of PC, G and C diet groups with significant ($P<.01$) differences between the former and the latter tow groups. The proportions of n-valeric acid tended to be higher in C diet group compared to those in G and PC diet groups.

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# 沖縄肉用山羊の生産、第一胃内性状及びその肉質に及ぼす飼料の影響

## Ⅰ．第一胃内性状に与える青苅り野草の影響

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第一胃フィステルを装着した四頭の沖縄肉用山羊に三種類の飼料即ち、(1)青苅り野草、(2)アルファルファ乾草キュウブ(3)アルファファ乾草キューブ（70%）と市販乳牛用濃厚飼料（ペレット）を給与し、ルーメン内のｐＨ、温度、生菌数、プロトゾア総数、プロトゾアの科及び亜科数、総揮発性脂肪酸量、各酸量及びその産生割合等の栄養生理諸元について比較検討した。現在沖縄の山羊飼養農家が普通に実施している飼い方に類似させるため、給与飼料のＤＣＰ及びＴＤＮ量は敢えて統一せず、ＮＲＣの標準に従い、体重の2.5%を給与した。青苅り野草は容積が大いため他の二種類の飼料に比べＤＣＰ及びＴＤＮの摂取量が減少した。青苅り野草給与山羊の第一胃内温度は他の飼料区に比べて低かった。アルファルファ乾草に濃厚飼料を30%添加した場合、第一胃内ｐＨは野草やアルファルファ乾草キューブのみの給与に比べて低く、生菌数、総プロトゾア数、Sprirotrichda、有尾及び無尾のEnto-diunium等の数、総ＶＦＡ、酢酸、プロピオン酸、酪酸及びN-吉草酸等の量は逆に多かった。また、青苅り草給与山羊は生菌数と有尾のEntodiniumで中間値、Ophryoscolexで最高値を示したものの、総ＶＦＡ量、酢酸、及びN-吉草酸では最低値であった。アルファルファ＋濃厚飼料では酪酸比が最も高く、一方青苅り野草は我々の予期に反してプロピオン酸比が高かった。

以上のことより、青苅り野草は濃厚飼料に比べて容積が大いためにＤＭ、ＤＣＰやＴＤＮの摂取量が抑制され、第一胃内の栄養諸元値が低くなった。従って、青苅り野草給与山羊は発育が悪く、屠殺年齢が遅れる分山羊が成熟しその刺身は味が酷く、山羊汁も美味で臭気の無い一因だと思われる。濃厚飼料給与山羊汁の臭気の一因として飼料中や第一胃内微生物の脂肪を構成する脂肪酸と共に第一胃内の高酪酸濃度の関与も考えられる。

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