The voluntary intake and digestibility, in sheep, of chopped and pelleted *Digitaria decumbens* (pangola grass) following a late application of fertilizer nitrogen

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1. Experiments were conducted with wether sheep in 1964 and 1965 fed pelleted or chopped mature *Digitaria decumbens* Stent (pangola grass) hay containing different crude protein contents. The voluntary intake of food, digestibility of dry matter and nitrogen, nitrogen retention and apparent time of retention of feed organic matter in the reticulo-rumen were measured. The different crude protein contents of the grass were obtained by applications of urea to the sward 14 and 28 days before cutting for hay in 1964 and 1965 respectively. This treatment increased the crude protein content of the dry matter from 4·9% to 8·7% in 1964 and from 3·7% to 7·2% in 1965. The size of the particles of the ground hay before pelleting is given.

2. The mean voluntary intake of chopped fertilized grass was 10% and 54% greater than that of the unfertilized; the voluntary intake of pellets made from fertilized grass was 35% and 75% greater than of those made from the unfertilized grass in 1964 and 1965 respectively.

3. The voluntary intake of pellets of unfertilized grass was 7% and 14% greater than that of chopped unfertilized grass; the voluntary intake of pellets of fertilized grass was 32% and 30% greater than that of chopped fertilized grass in 1964 and 1965 respectively.

4. The digestibility of the pellets was less than that of the chopped grass.

5. The apparent digestibility of the feed nitrogen was increased by the fertilizer nitrogen, but grinding and pelleting had no consistent effect. Sheep eating chopped or pelleted fertilized hay were in positive nitrogen balance.

6. The apparent retention time of organic matter in the reticulo-rumen was longer when the sheep were eating chopped hay than when they were eating pellets. In 1964 the apparent retention time of organic matter in the reticulo-rumen was shorter for chopped and pelleted unfertilized grass than for chopped and pelleted fertilized grass, but in 1965 the order was reversed.

7. The relationship between voluntary intake, apparent retention time of organic matter in the rumen and the protein content of the food is discussed.

The crude protein content of mature *Digitaria decumbens* Stent (pangola grass) can be increased by applying fertilizer nitrogen to the grass several weeks before cutting, but it is not known whether there is a corresponding increase in feeding value (Kretschmer, 1965). An increase in feeding value might be expected since the voluntary intake of *D. decumbens* is positively correlated with the crude protein content when less than approximately 7% (Milford & Minson, 1965). Campling & Freer (1961) have also shown that the voluntary intake of cows fed oat straw containing 3% crude protein can be increased by infusing urea into the reticulo-rumen. However, Minson & Pigden (1961) found that the voluntary intake of sheep fed wheat straw and of steers fed oat straw was decreased when urea was fed.

When roughages are finely ground and pelleted there is usually an increase in the rate of passage of food through the reticulo-rumen (Blaxter, Graham & Wainman,

1956) and an increase in the voluntary intake by both sheep and cattle. The increase in voluntary intake is not constant, but varies with the quality of the roughage (Minson, 1963). Large increases in voluntary intake are usually found with roughages of low quality (Heaney, Pigden, Minson & Pritchard, 1963; Minson, 1963). Grinding and pelleting mature *D. decumbens* of low crude protein content might therefore be expected to lead to large increases in voluntary intake. However, Egan (1965) has recently demonstrated that a physiological mechanism other than rumen distension may control the voluntary intake of low-protein roughages.

A study was therefore made of the voluntary intake and digestibility of *D. decumbens* hay containing two levels of crude protein; the hay was either chopped or coarsely ground and pelleted.

EXPERIMENTAL

Foods. A pure sward of *D. decumbens* was established in 1957 at Beerwah in south-eastern Queensland on a low-lying site with a low humic gley to humic gley soil (Bryan & Sharpe, 1965). The sward was cut on 21 January 1964, the grass discarded and urea applied to the whole area the same day at the rate of 100 kg/acre. One half of the area received a second application of 100 kg urea/acre on 31 March 1964. In the following 4 days 0·50 in. of rain fell. The two areas were cut on 13 April 1964, and the grass was made into hay, drying being completed in a grass drier with an inlet temperature of 85°. In the following season the sward was cut on 16 December 1964, the grass removed and urea applied to the whole area the same day at the rate of 100 kg/acre. One half of the area received a second application of 150 kg urea/acre on 10 February 1965. In the following 5 days 0·68 in. of rain fell. Both areas were cut on 10 March 1965 and the grass was made into hay. No rain fell during haymaking.

In each year there was, accordingly, one batch of hay made from unfertilized grass and one from fertilized grass. The four hays were chopped to 0·5–1·0 in. with a chaff cutter and half of each batch was weighed into sacks each containing 10 lb. Samples were taken for dry-matter determination by drying at 100° and subsequent analysis for nitrogen by the Kjeldahl method, ash by incineration at 500° and soluble carbohydrate by the anthrone method (Deriaz, 1961). The remaining half of each batch of hay was ground in a hammer-mill fitted with a $\frac{3}{16}$ in. screen in 1964 and a $\frac{3}{32}$ in. screen in 1965, and made into pellets 13 mm in diameter and 20–30 mm long. The size of the particles of ground roughage was measured by shaking mechanically for 90 min a 20 g sample of ground roughage through a series of test sieves (US standard sieves nos. 20, 40, 60, 80, 100 and 200). The bulk density of the pellets was determined by weighing the quantity that filled a 25 l. bucket.

Sheep and housing. Twelve merino wethers weighing between 34 and 45 kg were used to measure voluntary intake in 1964 and twenty wethers weighing between 36 and 53 kg in 1965. The sheep were drenched at the beginning of the trial with thiobendazole to reduce any effects of internal parasites. Each sheep was fitted with a canvas harness and faeces collection bag (Weston, 1959) and kept indoors in a galvanized iron metabolism cage fitted with urine shutes.

The weight of the sheep was measured with a platform scale at the beginning and end of the 10-day digestion trials. Metabolic size was calculated as the mean body-weight (W) (kg) raised to the 0·75 power (Kleiber, 1932).

Determination of voluntary intake of food. The sheep were fed all the feed they would consume with the minimum of feed selection since selection would affect the comparison between chopped and pelleted feeds (Heaney *et al.* 1963). *Ad lib.* feeding conditions were ensured by offering on the 1st day about 250 g feed in excess of the expected voluntary intake and this level of excess feed on offer was maintained throughout the trial. Uneaten feed was only removed at the end of the preliminary or measurement periods. Each feed was given to three sheep. In 1964 a 12-day preliminary period was allowed for the sheep to become accustomed to the feed. Uneaten food was removed at the end of the 12 days and the voluntary intake determined during the next 10 days with *ad lib.* feeding. Feed residues were collected at the end of the 10-day measurement period. This was followed by a further 7-day period of *ad lib.* feeding, but these results will not be reported in this paper.

In a second feeding period in 1964 the sheep given pellets in the earlier period were offered chopped hay and those given chopped hay received pellets. Only the physical form being offered was altered. Sheep on the hay from unfertilized or fertilized grass in the first period received the same hay in the second period. The feeds were offered in a 12-day preliminary period followed by a 10-day measurement period.

In 1965 the two cuts of hay were each fed to five sheep in a trial with a 7-day preliminary period and a 10-day period in which voluntary intake was determined; the physical form of hay offered was then reversed, as described for the previous year, and the measurements were repeated.

All results have been expressed as the voluntary intake per unit metabolic size.

Digestibility. The faeces were collected daily and stored at −18° during the periods of 10 days in which voluntary intake was measured. At the end of the collection period, the faeces from each sheep were weighed, mixed and sampled for dry-matter determination. The dried faeces were ground and analysed for nitrogen.

Nitrogen retention. Urine was collected each morning, stored at −18° and, at the end of the 10-day collection period, thawed, weighed, mixed and sampled for nitrogen determination. The nitrogen retention was calculated as the difference between the quantity of nitrogen apparently digested and the quantity excreted in the urine.

Feed retention in the reticulo-rumen. Two wethers fitted with large rumen fistulas were kept in a controlled-environment room and fed known quantities of the chopped or pelleted hay every hour for 7 days using an automatic feeder (Minson & Cowper, 1966). The contents of the reticulo-rumen were then removed, weighed and sampled for determination of dry matter at 100°, total nitrogen and ammonia (McDonald, 1948). The dried digesta were ground and analysed for total ash. Each feed was given at two levels shown in Table 4—a high level close to the maximum voluntary intake and another approximately 50% of the maximum voluntary intake. The apparent retention times of the organic matter were calculated by dividing the total organic matter in the reticulo-rumen by the quantities of organic matter fed each hour (Minson, 1966).

RESULTS

Feed composition

The crude protein content of the grass was increased in both years when fertilizer nitrogen was applied 14 and 28 days before cutting (Table 1). These results are in agreement with those previously reported by Ferguson (1948) and Kretschmer (1965). When the crude protein content was increased by fertilizer nitrogen the soluble carbohydrate content was decreased. In 1964 the ash content of the hay made from fertilized grass was higher than of that from unfertilized grass, but in the following year there was no difference in the ash content.

Table 1. *Chemical composition of the herbages and bulk density of the pellets*

Date cut	Second application of urea (kg/acre)	Dry matter (%)	Crude protein (g/100 g dry matter)	Soluble carbo-hydrates (g/100 g dry matter)	Ash (g/100 g dry matter)	Bulk density of pellets (g/l.)
13 April 1964	0	89·3	4·9	17·7	3·2	490
	100	91·5	8·7	12·6	3·6	590
10 March 1965	0	87·4	3·7	14·0	3·8	730
	150	89·1	7·2	7·9	3·8	640

Table 2. *Distribution of particle size of the ground grass before pelleting as determined by sieving through US Standard test sieves (g retained/*100 *g sieved)*

Sieve size	Sieve opening (mm)	1964 Fertilized	1964 Unfertilized	1965 Fertilized	1965 Unfertilized
20	0·84	19	20	4	6
40	0·42	51	50	40	48
60	0·25	16	16	25	21
80	0·177	4	4	7	6
100	0·149	4	3	7	6
200	0·074	5	5	13	10
Tray		1	2	4	3

In 1964 sieve tests on the ground hay before pelleting showed no differences, between the unfertilized and fertilized hay, in the proportion of the feeds that were retained on the six sieves (Table 2). In 1965 ground hay from grass that had received a late application of fertilizer had a slightly smaller particle size than ground hay made from the unfertilized grass, and ground hay made from both fertilized and unfertilized grass had a smaller particle size than in the previous year (Table 2); this was presumably due to the smaller screen size in 1965. The bulk densities of the pellets made from the coarsely ground hay in 1964 were lower than those made from the finely ground hay in 1965 (Table 1).

Voluntary intake

In both years the voluntary intake of all feeds except one was lower in the second measurement period than in the first period (Fig. 1). The decrease in both years was greater in sheep offered feeds with a low nitrogen content than in sheep offered hay from grass that had received a late application of fertilizer nitrogen.

The mean results for the two measurement periods in each year are shown in Table 3. Application of fertilizer nitrogen increased the voluntary intake of chopped hay by 10% and 54% in 1964 and 1965 respectively, but only in the 2nd year was the difference significant ($P < 0{\cdot}01$). The voluntary intake of pellets was significantly increased ($P < 0{\cdot}01$), by 35% and 75% in the 2 years, when fertilizer nitrogen was applied.

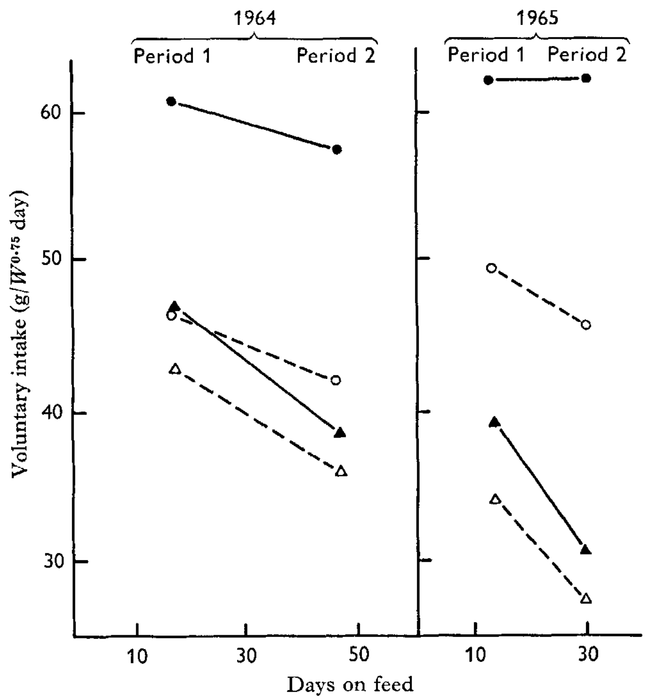

Fig. 1. Voluntary intake by sheep of chopped hay from fertilized (○---○) or unfertilized (△---△) grass and of pellets made from fertilized (●—●) or unfertilized (▲—▲) grass. W, body-weight in kg.

Grinding and pelleting hay made from unfertilized grass increased intake by 7% and 14% in 1964 and 1965 respectively. Neither difference was significant ($P > 0{\cdot}05$). When fertilized hay was pelleted, voluntary intake was significantly ($P < 0{\cdot}01$) increased by 32% and 30% in 1964 and 1965 respectively.

Dry-matter digestibility

Mean digestibility coefficients for hay dry matter in the two feeding periods are presented in Table 3. There was no significant effect of late application of fertilizer nitrogen on the dry-matter digestibility of chopped or pelleted hays.

Grinding and pelleting decreased the dry-matter digestibility of hay made from unfertilized grass by 7·9% and that from fertilized hay by 6·4% in 1964. Both differences were significant ($P < 0{\cdot}05$). In the following year the decreases in digesti-

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Table 3. *Mean values with their standard errors for voluntary intake, digestibility coefficients for dry matter and nitrogen, and nitrogen retention of sheep fed on hay made from fertilized or unfertilized grass*

Treatment of grass	Form of hay	Voluntary intake (g dry matter/$W^{0.75}$ day)		Digestibility of dry matter (%)		Apparent digestibility of N (%)		N retained (g/day)	
		1964	1965	1964	1965	1964	1965	1964	1965
Control	Chopped	40·2 ± 1·6	31·0 ± 1·8	53·1 ± 2·0	48·3 ± 1·6	31·1 ± 1·8	8·4 ± 2·5	−0·1 ± 0·1	−0·7 ± 0·1
	Pelleted	43·2 ± 2·0	35·3 ± 2·9	45·2 ± 1·8	44·7 ± 2·5	19·5 ± 2·4	11·8 ± 1·5	−0·6 ± 0·2	−0·8 ± 0·1
	Difference	+3·0 NS	+4·3 NS	−7·9**	−3·6 NS	−11·6**	+3·4 NS	−0·5 NS	−0·1 NS
Fertilized	Chopped	44·1 ± 2·0	47·7 ± 1·4	51·7 ± 0·6	51·8 ± 0·5	48·5 ± 0·9	50·3 ± 0·8	0·7 ± 0·4	2·5 ± 0·1
	Pelleted	58·4 ± 1·9	61·9 ± 1·8	45·3 ± 1·0	48·0 ± 1·0	47·4 ± 2·0	48·0 ± 1·0	2·8 ± 0·6	3·8 ± 0·2
	Difference	+14·3**	+14·2**	−6·4**	−3·8**	−1·1 NS	−2·3 NS	+2·1*	+1·3**
Change caused by fertilizing	Chopped	+3·9 NS	+16·7**	−1·4 NS	+3·5 NS	+17·4**	+41·9**	+0·8 NS	+3·2**
	Pelleted	+15·3**	+26·6**	+0·1 NS	+3·3 NS	+27·9**	+36·2**	+3·4**	+4·6**

1964, mean for six sheep for 10 days; 1965, mean for ten sheep for 10 days. W, body-weight in kg; NS, not significant. *$P < 0.05$; ** $P < 0.01$.

bility caused by grinding and pelleting were smaller, 3·6% and 3·8% respectively, and only the second difference was significant ($P < 0.05$).

Apparent digestibility of nitrogen

The apparent digestibility of the nitrogen in both the chopped and pelleted hay was significantly ($P < 0.01$) increased by the application of fertilizer nitrogen to the grass (Table 3). Pelleting had a variable and usually a non-significant effect on the apparent digestibility of the nitrogen.

Nitrogen retention

The nitrogen retention in sheep eating chopped hay or pellets made from grass that had received fertilizer nitrogen was higher than in sheep offered chopped or pelleted hay made from unfertilized grass in both years (Table 3). Negative nitrogen retentions were obtained with both chopped and pelleted hay made from unfertilized grass. In both years the greatest losses of nitrogen were obtained with pelleted hay made from unfertilized grass, but in neither year was the difference in nitrogen retention between pelleted and chopped hay significant. Grinding and pelleting increased significantly ($P < 0.05$) the nitrogen retention of sheep fed hay made from fertilized grass.

The percentage of the digestible nitrogen retained from the fertilized grass varied between years and between chopped and pelleted hay. When fed chopped hay from fertilized grass the sheep retained 15% of the digested nitrogen in 1964 and 51% in 1965. When the hay was ground and pelleted, the retention of digestible nitrogen was 46% and 63% in 1964 and 1965 respectively.

Feed retention in the reticulo-rumen

The chopped and pelleted hay made from fertilized grass were each given at two levels, but the chopped hay and pellets from the unfertilized grass were given at only one level (Table 4). At the high level of intake the total contents of the reticulo-rumen and the dry-matter percentage were higher than those found at the low level of feeding. When the pellets were fed, the contents of the reticulo-rumen were generally less than with the same quantity of chopped hay, but there was no consistent difference in the dry-matter percentage of the contents of the reticulo-rumen.

Grinding and pelleting all four hays led to a small decrease in the quantity of organic matter retained in the reticulo-rumen and the apparent retention times for the pellets were lower than those for the same amount of chopped hay (Table 4). At the high level of feeding more organic matter was apparently retained in the reticulo-rumen, but the apparent retention time was lower than at the low level of feeding. In 1964 the fertilized grass was apparently retained longer than the unfertilized grass, but in the following year the trend was reversed.

The ammonia concentrations in the reticulo-rumen were unaffected by the level of feeding, but the proportion of the total nitrogen present as ammonia decreased with an increase in level of feeding (Table 4). Both the ammonia concentration and the

Table 4. *Quantities of organic matter and nitrogen fed, total rumen contents, composition of the digesta, and apparent retention times of sheep fed on hay made from fertilized and unfertilized grass*

Year	Fertilizer applied (kg urea/acre)	Form of hay	Level of feeding	Intake of organic matter (g/h)	Intake of nitrogen (mg/h)	Rumen contents: Weight (g)	Rumen contents: Dry matter (%)	Rumen contents: Organic matter (g)	Rumen contents: Nitrogen (g)	Rumen contents: Ammonia (mg/100 g rumen contents)	Rumen contents: Ammonia (mg/g rumen N)	Apparent retention time of organic matter (h)
1964	0	Chopped	Low	12·1	95	3860	7·0	236	6·8	10·0	56	19·6
		Pelleted	Low	12·1	95	3450	7·1	215	7·9	10·1	49	17·8
	100	Chopped	Low	12·5	174	3900	7·8	257	8·0	14·9	73	20·6
		Chopped	High	24·5	341	5360	9·0	442	12·9	14·6	60	18·0
		Pelleted	Low	12·1	168	3900	7·1	244	8·0	15·4	75	20·1
		Pelleted	High	25·2	351	4310	10·7	419	13·3	15·1	49	16·6
1965	0	Chopped	Medium	15·9	94	3860	11·6	409	9·4	6·5	27	25·7
		Pelleted	Medium	16·4	97	4040	10·7	398	9·0	6·4	29	24·3
	150	Chopped	Low	12·0	138	4630	6·8	282	7·5	11·9	73	23·5
		Chopped	High	24·5	282	4860	11·1	501	10·2	12·1	58	20·4
		Pelleted	Low	12·1	139	4180	7·7	254	7·4	10·4	59	21·0
		Pelleted	High	25·3	291	4500	10·6	427	9·8	10·2	47	16·9

proportion of the total rumen nitrogen present as ammonia were lower when chopped or pelleted hay made from unfertilized grass was fed. Grinding and pelleting had no consistent effect on rumen ammonia concentration.

DISCUSSION

This study has shown that when the crude protein content of the feed was low, grinding and pelleting had little effect on voluntary intake. With unfertilized *D. decumbens*, containing 4·7% or 3·7% crude protein, only minor non-significant responses to grinding and pelleting were found. This is in agreement with some published results (Campling, Freer & Balch, 1963; Foot, 1964; Campling & Freer, 1966), but in direct contrast to the majority of experiments in which poor-quality rations were pelleted (Minson, 1963). However, Minson (1963) pointed out that most of the results reviewed were obtained with roughage rations containing a high proportion of lucerne; crude protein therefore was probably not a limiting factor. The existence of a crude-protein deficiency in sheep receiving the pellets made from the unfertilized grass is confirmed by the fact that large increases in voluntary intake were found when the fertilized *D. decumbens* was ground and pelleted.

The failure of grinding and pelleting to increase the voluntary intake of unfertilized grass could have been caused by a failure to grind the feed sufficiently fine. However, different grinder screen sizes were used in the 2 years and despite the smaller particle sizes obtained in the 2nd year (Table 2) the increase in voluntary intake following pelleting was 4·3 g/$W^{0.75}$ compared with 3·0 g/$W^{0.75}$ in 1964. Large increases in voluntary intake were obtained by grinding and pelleting the hay made from fertilized grass, although the particle size distribution of the ground hay was similar to that of the ground hay from unfertilized grass. With all pelleted feeds, further subdivision of the particles by the sheep may have been necessary before the larger particles could pass from the reticulo-rumen; it is possible that this subdivision could have been much slower for the ground and pelleted hay from unfertilized grass. It is unlikely, however, that the difference in response to grinding and pelleting hay from fertilized and unfertilized grass can be attributed to this effect since the retention time of organic matter in the reticulo-rumen was reduced when all feeds were pelleted (Table 4). Egan (1965) has shown that protein supplements improved the ability of sheep to deal with acetate and propionate loads imposed by intravenous injection and that associated with these improvements there were increases in voluntary intake. There appears to be no reason why this physiological mechanism was not controlling the voluntary intake of *D. decumbens*. If this mechanism were operating then the voluntary intake of the sheep in negative nitrogen balance should have decreased the longer the sheep were fed the nitrogen-deficient diet; this effect was found with the chopped and pelleted hay made from unfertilized grass.

The increase in voluntary intake by sheep of chopped hay that had received fertilizer nitrogen compared with the chopped hay made from the unfertilized grass was much larger in 1965 than in 1964. This difference in response was probably due to the much lower crude protein content and voluntary intake of the unfertilized grass in 1965 caused by different growth conditions in the 2 years (Bryan & Sharpe, 1965).

The digestibility of the dry matter of the chaff was slightly depressed by the late application of urea in 1964, but digestibility was increased in the following year. This variable effect of fertilizer nitrogen on digestibility is in agreement with previously published results (Minson, Raymond & Harris, 1960; Milford, 1960; Kane & Moore, 1961; Poulton & Woelfel, 1963). The variation in digestive efficiency of sheep appears to be increased by both a low nitrogen percentage in the grass and by pelleting. When eating the fertilized grass the digestive efficiencies of the sheep were less variable than when eating the unfertilized grass (Table 3). The between-sheep coefficients of variation in digestibility of dry matter for the unfertilized chopped hay were 9·2% and 10·4% in the 2 years and for fertilized chopped hay 2·8% and 3·2%. The between-sheep coefficients of variation for the sheep fed pellets were generally higher than for those fed chopped hay, but there was a similar difference between hays made from the unfertilized (9·8% and 17·4%) and fertilized (5·4% and 6·8%) grass. The cause of these differences in between-sheep variability is not known.

The apparent digestibility of the nitrogen was increased when the crude protein percentage of the chopped hay and pellets was increased by the fertilizer application. This result was expected since a close relationship has been reported between the apparent digestibility of crude protein and the crude protein content of tropical pasture species (Milford & Haydock, 1965). Negative nitrogen balances were found when the sheep ate unfertilized chaff and pellets, but positive balances were recorded with all the fertilized feeds. This increase in nitrogen retention was associated with an increase in both the apparent digestibility of the crude protein and the intake of digestible dry matter.

An application of fertilizer nitrogen to mature grass a short time before cutting for hay has been shown to increase the voluntary intake of mature *D. decumbens*, grown under ideal conditions with rain falling shortly after the urea was applied. Further work is required to determine whether a similar response can be obtained with other grasses grown in a range of environments.

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