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Nutritional Value of Vegetable Wastes as Livestock Feed

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ABSTRACT: A study was carried out to evaluate the nutritional value of waste from lettuce, green cabbage, red cabbage and cauliflower to determine their potential use for feeding to livestock. Vegetable wastes were dried in a solar tunnel drier. The crude protein (CP), ether extract (EE), total ash, acid detergent fiber (ADF) and neutral detergent fiber (NDF) were 24.1, 2.7, 24.7, 29.3 and 29.0%; 17.7, 2.3, 13.7, 25.6, and 28.7%; 11.9, 1.9, 8.8, 23.1 and 25.6%; 10.3, 0.5, 7.0, 16.1 and 19.6 % (DM basis) in cauliflower, lettuce, green cabbage and red cabbage, respectively. The gross energy (MJ/kg DM) in cauliflower and green cabbage (16.9 and 16.6) was higher than that observed in red cabbage and lettuce (14.1 and14.3). The red and green cabbage waste had higher net gas production (73 and 71 ml/g DM/12h) compared to the lettuce and cauliflower vegetable waste (51 and 48 ml/g DM/12h respectively). The green and red cabbage waste had significantly higher metabolizable energy (ME) (approximately 12 MJ/kg DM) than both lettuce and cauliflower waste (approximately 9 MJ/kg DM). The *in vitro* DM and OM digestibility (OMD) in green and red cabbage waste was significantly higher than in lettuce and cauliflower. The green and red cabbage waste had significantly higher short chain fatty acids (SCFA) (1.7 and 1.6 µmol) than lettuce and cauliflower (1.2 and 1.1 µmol). It was concluded that leafy vegetable waste (lettuce, green cabbage, red cabbage and cauliflower) is an excellent source of nutrients which can potentially be used after drying as an animal feed to reduce animal feeding costs and consequently increase farmers' profits. This would also help in waste management and the reduction of environmental pollution.

Keywords: Vegetable wastes; Lettuce, Cauliflower; Cabbage.

القيمة الغذائية لمخلفات الخضروات كعلف للحيوان في سلطنة عمان

عثمان محجوب،عصام كاظم، ياسمين الطاهر، صادق اللواتيا وعبد الرحيم الإسماعيلي

الملخص: تم إجراء دراسة لتقييم القيمة الغذائية لمخلفات الخضروات من الخس والزهرة والكرنب الأخضر والأحمر لتحديد إمكانية استخدامها كعلف للحيوان في عمان. تم تجفيف مخلفات الخضروات في مجففة شمسية وتم قياس المادة الجافة والتحليل التقريبي الكيميائي. كما تم إجراء تجربة في المختبر لقياس غاز الهضم ودرجة تحلل المادة العضوية الجافة. خفضت المجففة الشمسية وزن المادة الجافة في مخلفات الخضروات إلى 7.6% بعد حوالي 120 ساعة من التجفيف. كانت نسبة البروتين الخام والدهن الخام و الرماد الكلي والألياف المذابة في الحمض (ADF) و الألياف غير المذابة (NDF) كالآتي: 24.1 و2.7 و 24.7 و 29.3% ثم 17.7 و2.3 و13.7 و25.6% ثم 11.9 و1.9 و8.8 و23.1 و25.6% ثم 10.3 و0.5 و7.1 و16.1 و19.6% من المادة الخام لكل من الزهرة والخس والكرنب الأخضر والكرنب الأحمر على التوالي. وجد أعلى مستوى من الطاقة الخام في الزهرة والكرنب الأخضر (16.9 و16.6) وأدناها في الكرنب الأحمر والخس (14.1 و14.3 ميجا جول/كجم/مادة دافة). أنتج نوعا الكرنب الأخضر والأحمر غازاً أكثر (73 و71مل) من 12 ساعة وأكثر حتى نهاية التجربة من الخس والزهرة (51 و48 مل) على التوالي. كان للكرنب الأخضر والأحمر معدلات طاقة تمثيلية أعلى (12 ميجا جول/كجم) من الخس والزهرة (9 ميجا جول/كجم). كان للكرنب الأخضر والأحمر معدل هضم للمادة العضوية (81 و79%) أعلى من الخس والزهرة (61 و58%).أحتوى الكرنب الأخضر والأحمر على معدلات عالية من الأحماض الدهنية قصيرة السلسلة (1.7 و1.6 مايكرو مول) أعلى من الخص والزهرة (1.2 و1.1 مايكرو مول). كان أعلى معدل هضم للمادة الجافة في المختبر في الكرنب الأحمر والأخضر (88.5 و86.5%) يليه الخس (71.8%) والزهرة (75.2%) على التوالي. ويمكن الاستنتاج بأن مخلفات الخضروات الورقية مثل الخس والزهرة والكرنب الأخضر والأحمر مصدر ممتاز غني بالمكونات الغذائية يمكن استخدامه بعد التجفيف كمكون للأغذية الحيوانية ، مما سيقلل من تكلفة الغذاء وبالتالي يزيد من عائدات المزارع ، كما يمكن أن يساعد في التعامل مع مخلفات الغذاء وتخيض معدلات التلوث البيئي.

الكلمات المفتاحية: مخلفات الخضروات ، الخس، الزهرة ، الكرمب.

1. Introduction

Production of good, safe and cheap livestock feed is essential for profitable animal production but can exert significant pressure on natural resources and be in competition with the production of food for humans. For instance, it was reported that 53% of the cereals grown in the EU are fed to livestock [1] and that animal feed costs account for up to 70% of the cost of animal production. The FAO [2] indicated that the world will need about 73% more meat and 58% more milk in 2050 for the increasing human population. However, non-conventional feed resources such as natural range plant species and agricultural by-products may help to bridge the gap between demand and supply of animal feed. Vegetable and fruit wastes are envisaged to have good potential as feed resources [1].

The annual global food waste was estimated at about 1.3 to 1.6 G tonnes [1]. According to Thieme and Makkar [2] this is approximately one-third of global food produced and it has high environmental, economic and social impacts. The FAO [3] gave a very dismal account regarding food wastage, with the estimated annual direct economic consequences of food wastage at $750 billion. The global volume of food wastage is estimated at 1.6 billion tonnes of "primary product equivalents" and a wastage for the edible part of this amounts to 1.3 billion tones. Other harmful effects include methane emissions from food waste dumping and the unnecessary usage of large volumes of fresh water each year to produce food lost or wasted. It has been estimated that 1.4 billion hectares of land (28% of the world's agricultural area) is used annually to produce food that is lost or wasted. Most of the economic loss is suffered by developing countries, rather than developed countries [3].

Several studies have indicated that vegetable waste has good nutritive value and has potential for use as livestock feed [4,5,6]. Vegetable waste may be fed freshly chopped or processed, such as when dried, composited or in feed blocks. Vegetable waste could be transformed into value added products [7]. This non-conventional feed is highly sought after in arid regions, especially as maintenance feed during the dry season.

Cabbage and cauliflower leaves have been reported to serve as excellent sources of nutrients for ruminants and can economize the production of animals [4]. Therefore, the current study primarily aims to evaluate the nutritional value of vegetable waste collected from a local vegetable market as a livestock feed, after it has been dried in a solar greenhouse-like tunnel dryer. This is to reduce the cost of animal feeding, thereby increasing farmers' profits and reducing environmental pollution. The vegetable waste considered includes that of four leafy vegetables: lettuce (*Lactuca sativa*), green and red cabbage (*Brassica oleracea* var. *capitata* f. *rubra*) and cauliflower (*Brassica oleracea* B).

2. Materials and Methods

2.1 Vegetable waste collection and drying

Fresh vegetable waste from four leafy vegetables was collected from the nearby Al-Mawaleh fruit and vegetable market and transported to the Agricultural Experiments Station at Sultan Qaboos University in Muscat, Sultanate of Oman. The waste was weighed and spread out in a solar greenhouse-like tunnel dryer.

A 15 m long and 2 m wide solar tunnel dryer (Figure 1) was designed and constructed to dry up to 500 kg of fruit and vegetable wastes per batch. The first half of the tunnel base (air inlet side) was used as a flat plate air-heating solar collector and the other half as a dryer. The drying air was withdrawn from the air-heating region to the drying region of the semi-circular arched tunnel by means of fans. The fruit and vegetable wastes were uniformly distributed in the drying region. The drying temperature could be easily raised by some 5-30ºC above the ambient temperature inside the tunnel at an air velocity of approximately 0.5m/sec.

Figure 1. Drying vegetable waste in a drying solar tunnel.

2.2 Chemical analyses of feeds

Waste samples were dried then ground in a mill to pass through a 1 mm mesh sieve. The chemical composition of the finely ground samples of vegetable wastes were analyzed for proximate components [8] and for cell wall constituents [9, 10]. Gross energy (GE) was measured using a bomb calorimeter. The samples of different wastes were evaluated by using an *in vitro* gas production technique [11]. Short chain fatty acids were estimated according to the equation of Getachew *et al.*[12]. The *in vitro* dry matter digestibility (IVDMD) was determined after 96 h of digestion, following the methods of Njidda and Nasiru [13]. The data were analyzed by one-way analysis of variance using the analysis of variation model in SPSS PC package. Multiple comparison tests used Tukey's multiple-range test on SPSS [14].

3. Results and Discussion

3.1 Solar drying process

The efficiency of drying the vegetable waste in the solar tunnel was tested. A total weight of 415.6 kg of a random mixture from the four vegetables was evenly spread in the drying tunnel. After drying for 120 h (6 days) the final vegetable weight was 31.6 kg indicating that the vegetable waste contained 7.6% dry matter. This demonstrated that the drying tunnel is very efficient in drying vegetable waste. The dryer was constructed with a very simple design and could be easily adopted for such operations by Omani farmers [15]. Similar tunnels have previously demonstrated marked efficiency in drying dates and fish (sardines) [16,17].

The high moisture content of vegetable waste increases transportation costs and also increases its susceptibility to rapid spoilage, making it important to develop practical ways to preserve it. The current study indicated that the drying process was faster in a solar tunnel dryer than under natural open-air sun drying. It was possible to reach a low moisture content in the vegetable waste within 6 days in the solar tunnel dryer compared to 8-10 days in open air natural sun drying. The improvement in the quality of vegetable waste in terms of color, brightness and absence of signs of spoilage was clearly observable.

3.2 Chemical analyses of dried vegetable waste

The proximate chemical analyses of the four leafy vegetable wastes revealed that lettuce and cauliflower had the lowest dry matter content (Table 1), whereas the highest was observed in red and green cabbage. These values were comparable to those in published reports. For instance, Wadhwa and Bakshi [6] reported a DM of 10% and 13% for cabbage and cauliflower leaves, respectively. Mekasha *et al*. [18] also reported a DM of 14.0% for cabbage waste. Tobias Marino *et al*. [5] reported a DM value of 10.2% for cabbage and 5.7% for lettuce. Khan and Atreja [19] reported a DM content of 7.10% for both cabbage and cauliflower. Akinfemi [20] reported an extremely high DM content of 50.86% in cabbage. The high moisture contents in vegetable wastes should be taken into consideration during storage and processing. Drying using solar dryers such as the one described above would be an excellent option for processing to reduce moisture under Omani conditions.

Table 1. Chemical composition of vegetable waste*

Vegetable waste	Dry matter	Protein	Fat	Ash	ADF	NDF	Gross energy (MJ/kg DM)
Lettuce	5.15	17.74 ± 0.08	2.65 ± 0.08	14.74 ± 1.92	25.58 ± 0.07	28.67 ± 3.54	14.08
Green cabbage	11.00	11.85 ± 0.00	1.89 ± 0.00	8.75 ± 0.03	23.14 ± 0.08	25.55 ± 0.78	16.58
Red cabbage	10.86	10.36 ± 0.00	00.48 ± 0.09	7.04 ± 0.02	16.13 ± 0.04	19.59 ± 0.69	14.33
Cauliflower	7.07	23.05 ± 0.59	2.32 ± 0.12	13.67 ± 0.15	29.27 ± 0.49	28.97 ± 0.94	16.92

*All values except DM are expressed on % DM basis

The cauliflower had the highest CP followed by that in lettuce, then green cabbage, with the lowest in red cabbage. Published reports on CP vary greatly. Mekasha *et al*. [17] reported a 14.4 % CP value for cabbage waste whereas Akinfemi [19] reported a CP content of 18.4%. Wadhwa and Bakshi [6] reported a CP value of 20.4 and 16.1% for cabbage and cauliflower leaves, respectively, while Wadhwa *et al.* [4] reported a CP value of 20.4% for cabbage leaves and 16.1% for cauliflower leaves, respectively. Bakshi *et al*. [21] reported a CP content of 23.6% in fresh cauliflower leaves. Tobias Marino *et al*. [5] reported a CP value of 18.7% for cabbage and 28.2% for lettuce. Khan and Atreja [19] reported a CP of 22.40% in cauliflower. These studies, as well as the current study, indicate a general trend of high levels of CP in these leafy vegetables, which renders them a good source for feeding livestock.

The highest fat (EE) content in the current study was in lettuce and cauliflower, while green and red cabbages contained lower levels (Table 1). These levels are comparable to those reported previously for vegetable waste from these species. Mekasha *et al*. [19] reported a 1.5% EE (on DM basis) value for cabbage waste. Tobias Marino *et al*. [5] reported an extremely low EE value of 0.5% for cabbage and 0.2% for lettuce. Higher EE values were reported by Thakur and Bhatia [22], as 3.5 % in cauliflower leaves. Akinfemi [20] also reported an EE content of 6.02% in cabbage. Low fat levels are recommended for ruminant rations as high fat levels negatively influence rumen chemistry and biology.

The ash content in the vegetable waste varied greatly. The highest ash content was in lettuce followed by cauliflower, while green and red cabbages had lower ash contents. Wadhwa *et al*. [4] reported ash values of 14.0% and 17.2% (on DM basis) for cauliflower and cabbage leaves, respectively. An ash content of cauliflower leaves of 12.1% has also been reported [21]. Akinfemi [19] reported an ash content of 12.1 g/100g DM) in cabbage. Gupta *et al.*[23] reported 16.7% ash in cauliflower. Similarly an ash content of 14.7% in cauliflower was reported by Khan and Atreja [19]. It should be noted that high ash contents in non-conventional feeds pose a problem for their use in high proportions in mixed pelleted feeds.

In the current study, cauliflower had the highest ADF content followed by lettuce and green cabbage, whilst the lowest was is red cabbage. Values from published reports were within this range. Mekasha *et al*. [18] reported a 22.9% ADF value for cabbage waste. Wadhwa *et al.* [4] reported ADF values of 20.0% and 23.0% for cauliflower and cabbage leaves respectively. Bakshi *et al.* [21] reported an ADF content of 23.5% in fresh cauliflower leaves. The low ADF levels in vegetable waste indicates that it is easily digestible. The ADF represents the fraction of indigestible material in the forage, usually cellulose fiber coated with lignin plus silica.

The highest NDF content was in cauliflower followed by lettuce, and then green and red cabbage. Mekasha *et al*. (18) reported an NDF value of 27.2% for cabbage waste. Wadhwa *et al*. [4] reported higher NDF values of 28.0% and 34.0% for cauliflower and cabbage leaves respectively. Bakshi *et al.* [21] reported an NDF content of 28.0% for fresh cauliflower leaves, and Tobias Marino *et al*. [5] reported a NDF value of 20.9% for cabbage and 25.6% for lettuce. The level of NDF in animal rations is important as it influences its dry matter intake and the time of rumination. The concentration of NDF in feeds is also negatively correlated with energy concentration. Therefore, the ADF and NDF values found by the current study, and in the literature, indicate that vegetable waste is a good potential livestock feed component, as it would make ruminant feeds more digestible.

The highest gross energy (MJ/kg DM) in the current study was in cauliflower and green red cabbage followed by red cabbage and lettuce. Mekasha *et al*. [18] reported a comparable value of 17.5 MJ/kg DM gross energy for cabbage waste. Wadhwa *et al*. [4] reported an ME of 13.6 and 18.4 MJ/kg for cauliflower and cabbage leaves, respectively. DM indicates a similar trend of cabbage high energy value.

In general, chemical analyses of waste from all four leafy vegetables indicated that they had high CP and low fat and fiber contents as well as having low ADF and NDF contents. This indicates that they have a good potential to be used in ruminant diets. This is supported by previous studies. For instance, Wadhwa *et al*. [4] reported that cauliflower leaves supplemented with minerals and common salt could sustain the body weight of bucks without adverse effects on their health. It should also be noted that published information on the composition of vegetable waste varies considerably. This may be attributed to several factors which can affect the chemical composition of feed, including the stage of growth, maturity, species or variety, soil types and growth environment [24].

3.3 *In vitro* digestion of vegetable waste

The gas volume produced over 96 hours is given in Figure 2. The two cabbage vegetable wastes clearly produced more gas from 12 h on until the end of the experimental period. The lettuce and cauliflower vegetable waste produced significantly less gas throughout the experimental period. Both cabbage wastes equally produced the highest amount of gas, whereas the lettuce and cauliflower produced lower gas volumes (Table 2). This range of total gas production between 3 to 96 h was comparable to reports for waste from the same vegetable species.

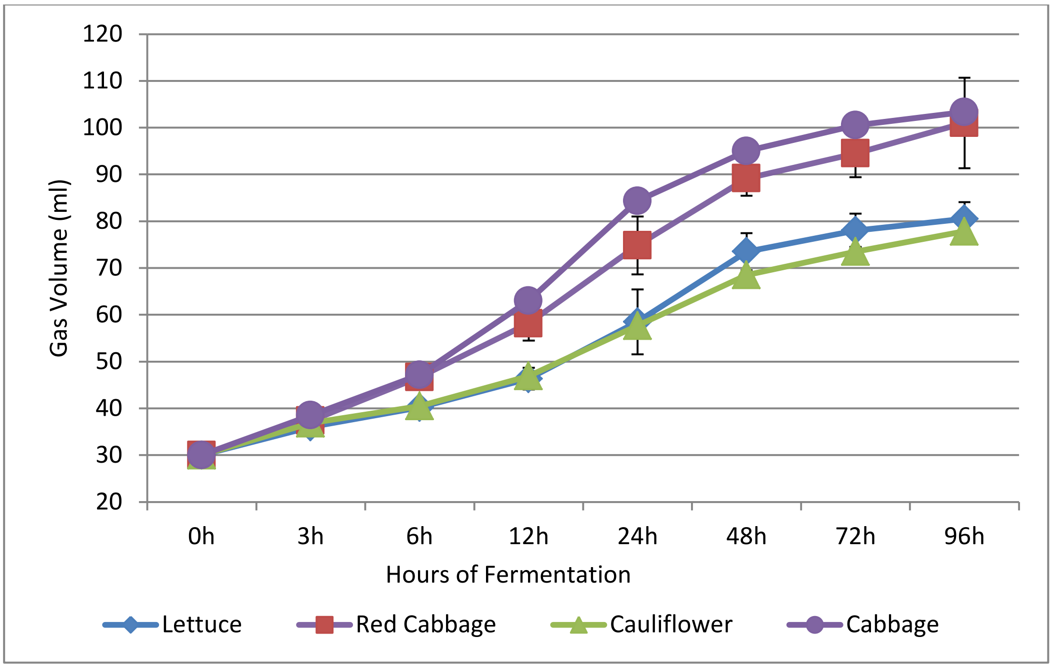

Figure 2. *In vitro* gas production pattern from four leafy vegetable waste.

Tobias Marino *et al*. [5] reported ranges of 10-60, 6-51 and 6-47 ml/200 mg OM for cabbage, lettuce and cauliflower, respectively. High gas production indicates a good potential for rumen fermentation. The low NDF in vegetable wastes was the reason for the high *in vitro* gas production and digestibility [20].

The green and red cabbages in the current study had significantly higher ME than both lettuce and cauliflower (Table 2). Tobias Marino *et al*. [5] reported comparable ME values of 10.1% for cabbage and 8.9% for lettuce. Wadhwa *et al*. [4] reported values of 13.6 and 18.4 MJ/kg DM for cauliflower and cabbage leaves, respectively. The high ME levels for cabbage are in line with the higher gross energy levels reported in the current study. High energy levels in vegetable waste indicate their excellent potential as livestock feed. Tobias Marino *et al*. [5] reported ME levels that followed a similar pattern of gas production to the findings of the current study.

Table 2. Gas production parameters of lettuce, green cabbage, red cabbage and cauliflower vegetable waste.

Parameter	Lettuce		Green cabbage		Red cabbage		Cauliflower		Significance of difference
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Total gas (ml)	50.50 ^{b}	2.082	73.33^{a}	1.014	71.00 ^{a}	5.575	47.83 ^{b}	0.667	P<0.0001
ME (MJ/kg DM)	9.07 ^{b}	0.283	12.17 ^{a}	.138	11.86 ^{a}	0.758	8.71 ^{b}	0.091	P<0.0001
OMD (%)	60.86 ^{b}	1.851	81.16 ^{a}	0.901	79.08 ^{a}	4.956	58.49 ^{b}	0.593	P<0.0001
SCFA (µmol)	1.15 ^{b}	0.050	1.69 ^{a}	0.024	1.64 ^{a}	0.133	1.08 ^{b}	0.016	P<0.0001

ME (Metabolizable energy, MJ/kg DM) = 2.20 + 0.136*GV + 0.057*CP + 0.0029*CF (Menke & Steingass, 1988)
OMD (Organic matter digestibility) = 14.88 + 0.889*GV + 0.45*CP + 0.651*CF (Menke & Steingass, 1988)
SCFA (Short chain fatty acids) = 0.0239*GV -0.0601 (Getachew *et al.*, 1999)
Means on the same row with similar denoting letters do not differ significantly (P>0.05)

Similarly, the green and red cabbages had significantly higher OMD than both lettuce and cauliflower (Table 2). Tobias Marino *et al*. [5] reported a comparable OMD value of 79% for cabbage and 71.5% for lettuce. Calculations indicated that the green and red cabbages had significantly higher short chain fatty acids (SCFA) than both lettuce and cauliflower (Table 2). These findings add to the value of vegetable wastes as potential livestock feeds, provided they have been provided properly processed.

The red and green cabbages had the highest IVDMD values, whereas the lettuce and cauliflower had lower values (Figure 3). Mekasha *et al.* [18] reported comparable IVDMD values of 80.4% for cabbage waste. High IVDMD values indicate low cell wall constituents, which is in line with the low ADF and high NDF values reported earlier.

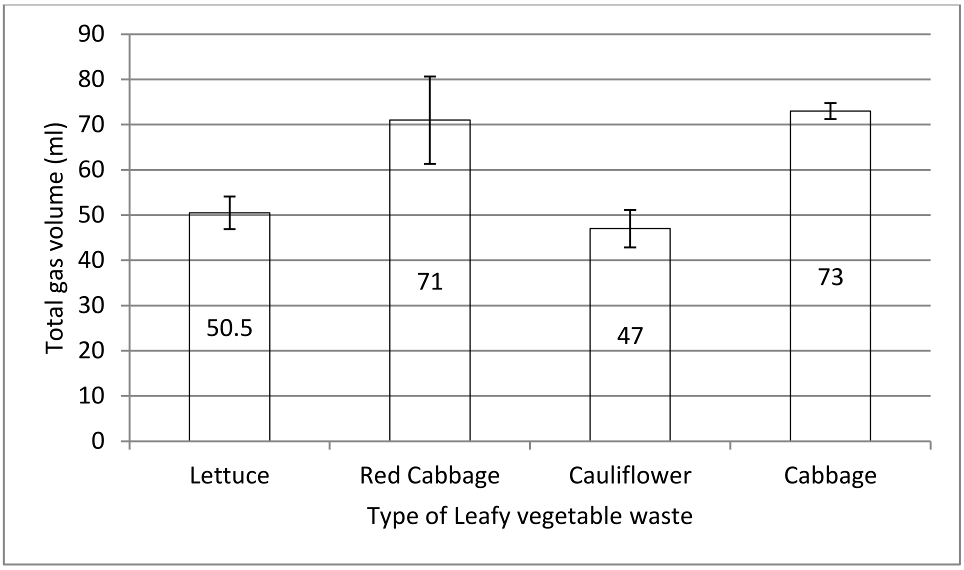

Figure 3. *In vitro* dry matter digestibility (IVDMD) after 96 h (%) = [(Initial DM input – DM residue-Blank)/ Initial DM input]×100 (Njidda and Nasiru [13]).

In general, the findings of the present study support published reports that based on chemical composition and digestibility, vegetable wastes proved to be excellent non-conventional feedstuffs equivalent to conventional green fodder.

4. Conclusion

Waste from leafy vegetables (lettuce, green cabbage, red cabbage and cauliflower) is a rich source of nutrients which may potentially be used after drying as animal feed. The effective and efficient utilization of vegetable wastes would reduce the cost of animal feeding, increase farmers' profits, generate an array of value-added products and help in waste management and the reduction of environmental pollution.

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