Use of an *In Vitro* Gas Production Technique to Evaluate Some Sugar-Industrial by Products and Sweetener Crops

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ABSTRACT

The present work aimed to identify the chemical composition of sugar cane bagasse (ScB), sugar beet pulp (SbP), stevia wastes (SW) and chicory pulp waste (CP) and also, to evaluate their nutritive value for animal feeding by using *in vitro* gas production technique. The potential of gas production technique is to predict fractions of rumen fermentable organic matter, kinetics of gas production, metabolizable and net energy, organic matter digestibility, short chain fatty acids and microbial protein were studied in some sugar -industrial by products and sweetener crops. A gas production was continuously measured by incubating samples in buffered rumen fluid from cannulated sheep for 96 h. Cumulative gas production was recorded at 3, 6, 9, 12, 24, 48, 72 and 96 h of incubation periods and kinetics of gas production was described. The present results indicated a significant diversity in proximate composition and total phenolic content of the utilized agro-materials which play an important role on rumen fermentation. Analysis of sugar cane bagasse, sugar beet pulp, stevia wastes and chicory pulp waste revealed that crude protein, ether extract, ash, crude fiber and nitrogen free extract varied from 3.44 to 8.39%, 0.93 to 4.85%, 3.36 to 10.74, 15.82 to 42.39% and 49.88 to 71.32%, respectively. There were significant ($P<0.05$) differences among feedstuffs and some combination with hay and sugar cane bagasse in terms of metabolizable energy (ME) (8.121 vs 11.314 MJ/kg DM), net energy (NE) (4.068 vs 6.544 MJ/kg DM), short chain fatty acids (SCFA) (90.595 vs 137.215 mM), microbial protein synthesis (65.445 vs 89.366 g/kg OMD) and organic matter digestibility (OMD%) (54.667 vs. 74.1%).

Keywords: *In vitro*, gas production, bagasse and sweetener crops

1. INTRODUCTION:

Increases in the world's population mean that food production must also increase. Using the crop residues and agro-industrial as animal feed are an economical and environmentally sound way for food processors to decrease waste discharges and to reduce waste management costs. The sale of by-products can also generate additional revenue. Livestock producers can save money if the by-products offer a less expensive source of nutrients than traditional feeds and if they permit acceptable animal performance. Crop residues and agro-industrial by-products play a more significant role in the nutrition of ruminants where they are consist of proteins, sugars and lipids along with particular aromatic and aliphatic compounds and, therefore, they could be cheap and abundant sources of fine chemicals, and other bioactive components such as carotenoids, phytoestrogens (Martin, *et al.*, 2012) and natural antioxidants, such as phenolic compounds, and functional compounds (Zhou *et al.,* 2009). Sugarcane bagasse and sugar beet pulp are considered the main by-products of the sugar industry. *Stevia rebaudiana* Bertoni is especially known for the sweetening principle contained in the leaves, which have attracted the attention of industrial produces because of their potential dietetic, alimentary and pharmaceutical interest (Chatsudthipong and Muanprasat, 2009). However, the potential use and practical implications of stevia as a sweetener in livestock diets is still a subject of research. The leaves of stevia contain a complex mixture of labdone diterpens, tritespenes, stigmasteral, tannis, volatile oils and eight sweet diterpene glycosides (Lemus-Mondaca *et al.*, 2012). Roots of chicory (*Cichorium intybus L.*) are a potential source of fructose for use as a sweetener in foods and are vegetatively agriculture plant with nutritional, medicinal and energetic potential (Toneli *et al.*, 2007). Chicory pulp is a suitable feed resource for beef cattle. Feed intake was significantly lower with chicory pulp addition. Because of the significant reduction in feed intake the cattle consuming the chicory pulp were significantly ($P \leq 0.05$) more efficient than those fed the beet pulp ration (Rush and Pelt, 1999). Recently, much attention has been focused on utilization of and/or methodology tested in improvement of crop residues and agro-industrial by-products for livestock feeding. The objective of our study was to evaluate the feeding value of berseem hay, rice straw and some sugar-Industrial by products and sweetener crops, *in vitro*.

2. MATERIALS AND METHODS:

2.1. Feedstuffs

Berseem hay (H), rice straw (RS) were used for comparing with industrial by-products and sweetener crops.

2.2. Sugar -Industrial by products and sweetener crops

1. Sugar cane bagasse (ScB): A waste product of the sugar factory after milling which represents about 43.62% of total crop was obtained from Technological Lab. at Sabahia Agric. Research Station, Agric. Research Center, Alexandria, Egypt
2. Sugar beet pulp (SbP): The pulp of sugar beet which is to be considered as a waste of beet sugar manufacture represent about 21.9% of total crop obtained at the factory (Delta beet sugar Company, Kafr El-Sheikh Governorate, Egypt).
3. Stevia wastes (SW): Stevia was harvested after 4 months and leaves were left to dry then subjected to extraction process to obtain most of sweeteners in the leaves according to Hassan *et al.* (2002). Residue after sweeteners extraction was used in this study.
4. Chicory pulp waste (CP): Chicory pulp after milling and extraction of inulin as described by Zeitoun et al. (2003). Then the residue after extraction and filtration was studies as a chicory pulp wastes.

2.3. Samples preparation

Samples of all Feedstuffs, sugar-industrial by-products and sweetener crops were dried at 40°C ± 2°C in electric oven (E. Schulg & Co. Inh. Franz. KG) until the moisture content reached 10% or less. Then they were ground in mill to pass a 1 mm sieve prior to chemical analysis and in vitro gas production measurements.

2.4. Analytical methods

Representative samples of berseem hay, rice straw, sugar cane bagasse (ScB), sugar beet pulp (SbP), stevia wastes (SW) and chicory pulp waste (CP) were subjected to dry matter (DM), organic matter (OM), ether extract (EE), crude fiber (CF) and ash determinations following the procedure of AOAC (1995). Nitrogen (N) content was measured by the Kjeldahl method (AOAC, 1995). Crude protein (CP) was calculated as N X 6.25. Total carbohydrate was calculated by difference. Total phenols (TP) content of sugar -industrial by products and sweetener crops were assayed colorimetrically using the Folin-ciocalteu method

(Gamez-Meza et al., 1999). The absorbance was measured at 750 nm using a Shimadzu 160 1 PC UV - visible Spectrophotometer.

2.5. Measurement of in vitro gas production

In vitro gas production was undertaken according to Menke and Steingass (1988). Rumen fluids were collected before morning feeding from three fistulated sheep fed berseem hay and commercial concentrate mixture twice a day. The rumen fluid was filtered through four layers of cheese–cloth and flushed with CO_2. The CO_2-flushed rumen fluid was added (1:2, v/v) to the buffered mineral solution (Onodera and Henderson, 1980), which was maintained in a water bath at 39^{o}C, and combined. All laboratory handling of rumen fluid was carried out under a continuous flow of CO_2. Samples (200 mg) of the air–dried feedstuffs were accurately weighed into glass syringes fitted with plungers. The syringes were pre-warmed at 39^{o}C before injecting 30 ml rumen fluid-buffer mixture into each syringe and excess gas was released. The syringes were incubated in a water bath at 39^{o}C. Two blank syringes containing 30 ml of the medium only were also included. All the syringes were gently shaken 30 min after the start of incubation and every one hour for the first 12 h of incubation, thereafter five times daily. The gas production was recorded at 3, 6, 9, 12, 24, 48, 72 and 96 hours of incubation. Total gas values were corrected for blank incubation which contained only rumen fluid. Cumulative gas production (Y) at time (t) was fitted to the exponential model of Ørskov and McDonald (1979) as follows:

Gas (Y) = a + b (1-exp-ct), where; a = gas production from the immediately soluble fraction, b = gas production from the insoluble fraction, c = gas production rate constant for the insoluble fraction (b), t = incubation time.

The energy values and the percentages of organic matter digestibility of forages can be calculated from the gas produced on incubation of 200 mg feed dry matter after 24 h of incubation with the levels of crude protein, ash and crude fat (Menke *et al.*, 1979 and Menke and Steingass, 1988) as follows:

ME (MJ/kg DM) = 2.2 + 0.136*GP + 0.057*CP + 0.0029*CF2

OMD (%) =14.88 + 0.889 *GP + 0.45 *CP + 0.0651*A

Where: ME is the metabolizable energy, OMD (%) is the percentage of organic matter digestibility, GP is the 24 h net gas production (ml/200 mg DM) after 24 h of incubation. CP, crude protein (%); CF, crude fat (%) and A, ash content (%).

NE (Mcal/Ib) = [2.2 + (0.0272 × Gas) + (0.057 × CP) + (0.149 × CF)] / 14.64

Where: NE is the net energy; Gas, the net gas production in ml from one-gram dry sample after 24 h of incubation; CP, crude protein (%); CF, crude fat (%) then, net energy unit converted to be MJ/kg DM.

Short chain fatty acids (SCFA) were calculated according to Getachew *et al.* (2005) as follows:

SCFA= (-0.00425 + 0.0222 GP) × 100

Where: GP is 24 h net gas production (ml/200 mg DM).

Microbial protein was calculated as 19.3 g microbial nitrogen per kg OMD according to Czerkawski (1986).

2.6. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM). Significant differences between individual means were identified using least significance difference (LSD) multiple range test (SAS, 2000).

3. RESULTS AND DISCUSSION:

3.1. Proximate composition of by-product sugar industry and sweeteners from sugar crops and plants

The chemical compositions of the berseem hay, rice straw, leaf, heads, stalk and whole plant fractions of sweet sorghum and bagasse are presented in Table 1. Results indicated great variations between the tested samples in their contents of CP, EE, ash, CF and NFE contents. The organic matter (OM) content ranged from 82.25 to 93.88 % and the OM content was lower for RS than for other tested feedstuffs. Nitrogen free extract varied from 40.42% to 71.32 % among such raw materials. It was high in chicory pulp, low in rice straw. The percentage of total carbohydrate of sugar cane bagasse, and chicory pulp was 45.30 % and 65.53%, respectively (Massoud, 2004). These variations may be due to the difference in cultivation conditions and genotype. The berseem hay had the highest crude protein content (15.32%), followed by sugar beet pulp (8.38%), stevia leaves wastes (8.19%), chicory pulp (5.35%), rice straw (4.85%) and sugar cane bagasse (3.44%), respectively. Results obtained approximately similar to those results obtained by Yüksel *et al.*, 2009, but different from the results obtained by Jenkins, 2010. The present date showed that the lowest value of crude fat was 0.47% for rice straw, while the highest value was 4.85% for stevia leaves wastes. Ash content was high in rice straw (17.75%), berseem hay (11.2%) and stevia leaves wastes (10.74%), while the value of ash for sugar cane bagasse (3.36%) was low and nearly closed in sugar beet pulp (5.01 %) and chicory pulp (5.61 %). Theander and Aman, (1984) showed that the ash content is usually high in the leaf fraction of cereal straws due to a high content of silica. Sugar cane bagasse had the highest fiber content (42.39%) then rice straw (36.51 %), while the values of CF were 29.82% in berseem hay, 21.58 %.in sugar beet pulp, 16.02 % in chicory pulp, and 15.82 % in stevia leaves wastes. According to Beshay (2001) the bagasse of sugar cane contained 0.65 to 1.15% fat and 34.49 to 52% crude fiber. Monti *et al.*, (2005) found that crude protein and ash ranged from 8.56 to 15.73% and 9.58 to 13.75%, respectively in chicory roots. Table (2) shows the extracted yield and total phenolic content obtained from the different plant materials used. The stevia wastes contained the highest amount of methanolic extracted yield (18.66%), while sugar beet pulp and sugar cane bagasse obtained the lowest amount (3.31 and 3.89 %), respectively. The total phenolic content appeared to be proportional to the extracted yield (%). These variations in total phenolic content could be due to the specific nature of the plant type. Massoud (2004) found that the phenolic content in sugar cane farm waste, sugar beet farm waste and chicory farm waste are within the range of 3.85% to 4.12%, on the other side the phenolic content in industrial waste of the same material are represented almost the half (1.68-2.56%) of the phenolic content in farm waste.

Table 1: Proximate composition of hay, rice straw, sugar industry by-products and sweeteners from sugar crops and plants (on dry basis)*

Type	OM %	CP* %	EE %	Ash %	CF %	NFE **%
H	88.80±0.45	15.32±0.17	1.03±0.10	11.20±0.23	29.82±0.15	42.63±1.96
RS	82.25±0.87	4.85±0.26	0.47±0.09	17.75±0.56	36.51±0.22	40.42±2.01
ScB	93.11± 0.51	3.44±0.34	0.93 ±0.16	3.36±0.79	42.39± 1.23	49.88 ± 2.52
SbP	92.92± 1.07	8.39 ±0.25	0.78 ±0.33	5.01 ±0.64	21.58± 1.15	64.24 ± 2.37
CP	92.44± 1.08	5.35 ±0.62	1.70 ±0.19	5.61 ±0.31	16.02± 0.54	71.32. ± 1.66
SW	93.88± 0.14	8.19 ±0.97	4.85±0.33	10.74±0.65	15.82 ±1.03	60.40 ± 2.98

H= hay, RS =Rice straw, ScB= sugar cane bagasse, SbP= sugar beet pulp, CP= chicory pulp wastes SW= Stevia wastes. OM= organic matter, CP*= Crude protein, EE = ether extract, CF= crude fiber, NFE =nitrogen free extract
* Values are means ± standard deviations ** NFE were calculated by difference

Table 2: Methanolic extracted yield and total phenolic content of different industrial wastes of sugar and sweetener crops samples (on dry weight basis)*.

Sample of materials wastes	Methanolic extracted%	Total phenolic content%
Sugar cane bagasse	3.89 ± 0.3	**1.41 ± 0.6**
Sugar beet pulp	3.31 ± 1.1	**2.06 ± 0.5**
Stevia wastes	18.66± 1.4	**15.93 ± 0.7**
Chicory pulp	5.10 ± 0.2	**1.55 ± 0.6**

*values are means ± standard deviations

3.2. In Vitro Gas Production

Gas production for the means of the berseem hay (H), rice straw (RS), sugar cane bagasse (ScB), sugar beet pulp (SbP), stevia wastes (SW) and chicory pulp waste (CP) and the combination of by-products with hay is presented in Fig.1 and Table 3.

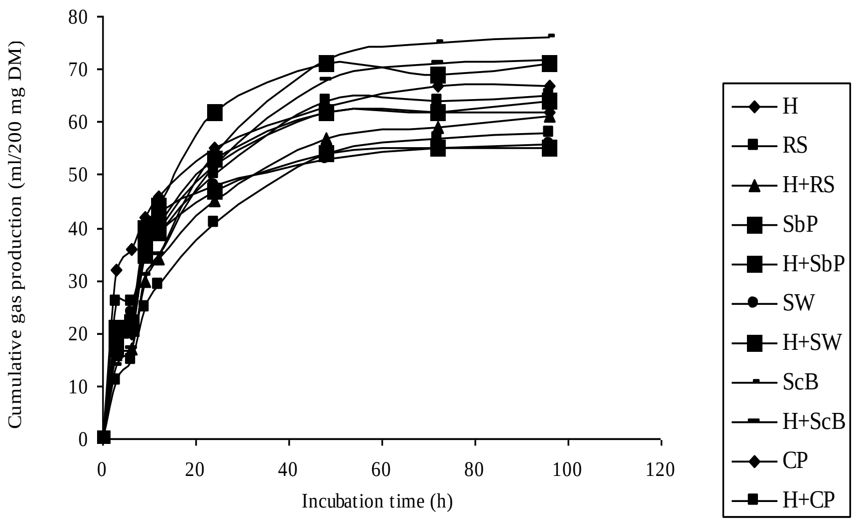

Fig 1. A cumulative gas production for hay (H), rice straw (RS), H+RS, sugar beet pulp (SbP), H+SbP, stevia wastes (SW), H+SW, sugar cane bagass (ScB), H+ScB, chicory pulp (CP) and H+CP

The cumulative volume of gas production increased with increasing time of incubation, and the differences in gas production occurring during the early hours indicated high differences in total gas produced at 24 h. There were significant ($P<0.05$) differences among the tested samples in terms of total gas production and parameters (Fig. 1 and Table 3). The produced gas at 96 h ranged from 55-76 ml/200 mg DM. Total gas produced at 96 h of incubation was significantly ($P < 0.05$) higher for the ScB, H+ScB and SbP than in other substrates. The highest GAS24, GAS96 and b were observed for the SbP. Haddi *et al.* (2003) suggested that interactions between NDF, CP, ADL and ash contents influenced the kinetics of gas production. Kamalak *et al.* (2005) noted considerable variations among alfalfa varieties in terms of gas production at all incubation times according to the differences in the chemical composition of the varieties of alfalfa.

Table 3. Cumulative gas production (ml/200 mg DM) after 12, 24, 48, 72, 96 h of incubation and gas production parameters in berseem hay, rice straw, sugar cane bagasse, sugar beet pulp, stevia wastes and chicory pulp waste and the combination of by-products with hay.

Substrate	12	24	48	72	96	a	b	c
H	40^{bc}	52^{bc}	62^{b}	62^{ef}	62^{ef}	3.726^{cd}	58.802^{c}	0.077^{b}
RS	29^{e}	41^{d}	54^{c}	57^{fg}	58^{fg}	2.410^{d}	56.065^{cd}	0.052^{c}
H+RS	34^{d}	45^{cd}	57^{c}	59^{de}	61^{de}	6.216^{b}	54.448^{d}	0.055^{c}
SbP	44^{ab}	62^{a}	71^{a}	69^{bc}	71^{bc}	0.000^{f}	73.069^{a}	0.085^{b}
H+SbP	41^{bc}	53^{bc}	62^{b}	62^{d}	64^{d}	4.182^{c}	58.952^{c}	0.079^{b}
SW	43^{ab}	48^{c}	53^{c}	55^{g}	56^{g}	4.866^{c}	49.536^{e}	0.109^{a}
H+SW	39^{cd}	47^{c}	54^{c}	55^{g}	55^{g}	9.180^{a}	45.839^{e}	0.079^{b}
ScB	35^{d}	54^{bc}	72^{a}	75^{a}	76^{a}	1.327^{de}	76.053^{a}	0.050^{c}
H+ScB	35^{d}	52^{bc}	68^{a}	71^{ab}	72^{ab}	3.838^{cd}	69.315^{b}	0.050^{c}
CP	46^{a}	55^{b}	63^{b}	67^{cd}	67^{cd}	24.928	43.038	0.054
H+CP	39^{c}	50^{c}	64^{b}	64^{de}	65^{de}	16.926	49.371	0.048

a,b,c,d,e,f means within the same column with different superscripts are significantly different ($P<0.05$).

H = hay, RS = Rice straw, H+RS= hay + rice straw, SbP= sugar beet pulp, H+SbP = hay + sugar beet pulp, SW= Stevia wastes, H+SW= hay + stevia wastes, ScB = sugar cane bagasse, H+ScB = hay + sugar cane bagasse, CP= chicory pulp wastes, H+CP= hay + chicory pulp waste.

Estimated gas production rate (c) varied from 0.048 ml/h in H+CP to 0.109 ml/h in SW. The highest values of (c) was for SW then SbP while, the lowest values was for H+CP then ScB and H+ScB, respectively. The intake of a feed is mostly explained by the rate of gas production (c) which affects the passage rate of feed through the rumen, whereas the potential gas production (a + b) is associated with degradability of feed (Khazaal *et al.*, 1995).

3.3. Energy contents, organic matter digestibility, short chain fatty acids and microbial protein

The predicted metabolizable energy (ME, MJ/kg DM), net energy (NE, MJ/kg DM), organic matter digestibility (OMD, %), short chain fatty acids (SCFA, mM) and microbial protein (MP, mg/kg DM) of berseem hay (H), rice straw (RS), sugar cane bagasse (ScB), sugar beet pulp (SbP), stevia wastes (SW) and chicory pulp waste (CP) and the combination of by-products with hay is presented in Table 4. The present data show that the ME and NE ranged from 8.12 – 11.31 and from 4.07 – 6.54 MJ/kg DM, respectively. The ME were higher ($P<0.05$) for SbP and H+SbP than for RS, H+RS, SW, H+SW, ScB and H+CP while, NE were higher ($P<0.05$) for ScB and H+ ScB than for SW and CP. The calculated organic matter digestibility from gas production values at 24 h was subsequently highest in SbP (74.1%) and lowest in RS (54.67%) (Table 4). The present results in agreement with Jenkins, 2010, who found that In vitro dry matter disappearance (IVDMD) was 67.3 and 76.1 % for chicory leaves and sugar beet pulp, respectively. Park *et al.*, 2005 suggested that beet pulp has a highly digestible fiber fraction, and is therefore considered to be both an energy and roughage source in beef cattle diets. Also, Rush and Pelt, 1999 showed that the fiber in beet pulp is highly digestible and has relatively high net energy value. However, chicory pulp is a suitable feed resource for beef cattle. Feed intake was significantly lower with chicory pulp addition. Palatability or very high water content of rations which reduced ration quality is potential reasons for decreased consumption of rations containing chicory pulp. Short chain fatty acids and microbial proteins ranged from 90.6-137.22 mM and 65.95-89.39 g/kg OMD, respectively. Microbial proteins and SCFA were significantly ($P<0.05$) higher for SbP than the other tested feedstuffs because SbP has a highly digestible fiber fraction. The sugar beet pulp (SBP) has great importance in beef cattle feeding programmes, since it has highly digestible fibre that may encourage the growth of the cellulolytic and hemicellulolytic microorganisms (Fluharty and Dehority, 1995). There are also reports that show that stevia and its extracts have antimicrobial properties that might influence the microbial population of the gut (Takahasshi *et al.*, 2001). Changes in gut microbial population have been shown to alter digestive enzyme activity, short chain fatty acids (SCFA) production and the health of the animals (Macfarlane and Cummings, 1991).

Table 4: Metabolizable energy (ME), net energy (NE), organic matter digestibility (OMD), short chain fatty acids (SCFA) and microbial protein (MP) synthesis prediction in berseem hay, rice straw, sugar cane bagasse, sugar beet pulp, stevia wastes and chicory pulp waste and the combination of by-products with hay.

Substrate	ME (MJ/kg DM)	NE (MJ/kg DM)	OMD (%)	SCFA (mM)	MP (g/kg OMD)
H	10.83^{ab}	5.74^{ab}	68.73^{b}	115.02^{b}	82.91^{b}
RS	8.12^{c}	5.81^{ab}	54.67^{d}	90.60^{e}	65.95^{e}
H+RS	9.19^{b}	5.75^{ab}	60.37^{c}	99.48^{d}	72.82^{c}
SbP	11.31^{a}	4.87^{bc}	74.10^{a}	137.22^{a}	89.39^{a}
H+ SbP	10.49^{ab}	5.24^{bc}	67.86^{b}	117.24^{b}	81.86^{b}
SW	9.39^{b}	4.07^{c}	61.94^{c}	106.14^{c}	74.71^{cd}
H+ SW	9.66^{b}	4.85^{b}	62.67^{bc}	103.92^{c}	75.60^{cd}
ScB	9.77^{b}	6.54^{a}	64.65^{bc}	119.46^{b}	77.99^{bc}
H+ ScB	10.06^{ab}	6.13^{a}	65.81^{b}	115.02^{b}	79.38^{bc}
CP	10.07^{ab}	4.11^{c}	66.55^{b}	121.68^{b}	80.28^{b}
H+CP	$9.\ 90^{b}$	4.86^{b}	64.53^{bc}	110.58^{b}	77.84^{bc}

A,b,c,d, means within the same column with different superscripts are significantly different ($P<0.05$).

H=Berseem hay, RS = Rice straw, H+RS= hay + rice straw, SbP= sugar beet pulp, H+SbP = hay + sugar beet pulp, SW= Stevia wastes, H+SW = hay + stevia wastes, ScB = sugar cane bagasse, H+ScB = hay + sugar cane bagasse, CP= chicory pulp wastes, H+CP = hay + chicory pulp waste.

ME = Metabolizable energy, NE = Net energy, OMD = Organic matter digestibility, MP = Microbial protein, SCFA = Short chain fatty acids.

4. CONCLUSIONS:

Although there are significant differences in the chemical composition of feed materials used in this study, all substrates, except rice straw, analyzed in this study were highly digestible with low to moderate protein content and could be included in ruminants diets to reduce feeding costs. Sugar beet pulp has a highly digestible fiber fraction, and is therefore considered to be both an energy and roughage source in beef cattle diets.

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استخدام طريقة إنتاج الغاز معملياً لتقييم بعض مخلفات صناعة السكر والمحليات

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تهدف الدراسة إلى تقييم اثنين من مخلفات صناعة السكر (مصاصة قصب السكر وبنجر السكر) ومحصولى الإستيفيا والشيكوريا من حيث التركيب الكيميائي وتقيم القيمة الغذائية باستخدام طريقة إنتاج الغاز معملياً. حيث أن طريقة إنتاج الغاز تساعد في التنبؤ بتخمر المادة العضوية في الكرش وميكانيكية إنتاج الغاز وقيم كلا من الطاقة الميتابوليزمية والصافية ومعامل هضم المادة العضوية وكذلك معرفة كمية الأحماض العضوية الطيارة والبروتين الميكروبي المنتجة من مخلفات صناعة السكر ومخلفات المحليات. تم قياس إنتاج الغاز عن طريق تحضين العينات تحت الدراسة لمدة ٩٦ ساعة في سائل يتكون من كلا من محلول منظم (buffer) وسائل الكرش المتحصل عليه من ٣ رؤوس من الاغنام المفستلة (ذات فستيولا في الكرش). تم تسجيل قيم الغاز المنتجة بعد ٣، ٦، ١٢، ٢٤، ٤٨، ٧٢، و٩٦ ساعة من التحضين. أوضحت النتائج وجود إختلافات معنوية في التركيب الكيميائي والمواد الفينولية للعينات تحت الدراسة. فلقد أختلف البروتين الخام من ٣.٤٤ – ٨.٣٩٪

والمستخلص الإثيرى من ٠.٩٣ – ٤.٨٥٪ والرماد من ٣.٣٦ – ١٠.٧٤٪ والألياف الخام من ١٥.٨٢ – ٤٢.٣٩٪ وكذلك الكربوهيدرات الذائبة تراوحت ما بين ٤٩.٨٨ – ٧١.٣٢٪ فى مصاصة قصب وبنجر السكر ومخلفات نبات الإستيفيا والشيكوريا على التوالي. كما يوجد إختلافات معنوية في قيم الطاقة الميتابوليزمية (٨.١٢١ – ١١.٣١٤ ميجا جول/كجم مادة جافة) والطاقة الصافية (٤.٠٦٨ – ٦.٥٤٤ ميجا جول/كجم مادة جافة) والأحماض الدهنية الطيارة (٩٠.٥٩٥ مليمول) والبروتين الميكروبي المخلق (٦٥.٤٤٥ – ٨٩.٣٦٦ جم/كجم مادة عضوية مهضومة) ومعامل هضم المادة العضوية (٥٤.٦٦٧ – ٧٤.١٪). بين المواد المستخدمة في الدراسة وكذلك مخاليط تلك المواد مع الدريس وقش الأرز.

الكلمات المفتاحية: إنتاج الغاز معملياً – المصاصة ومحاصيل المحليات.