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REGULAR ARTICLES

Dietary inclusion of restaurant food waste effects on nutrient digestibility, milk yield and its composition, blood metabolites of lactating Zaraibi goats, and their offspring performance

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Abstract

This study aimed to evaluate the effects of rations containing restaurant food waste (RFW) on nutrient digestibility, milk yield and its composition, and some blood parameters of lactating Zaraibi goats. In the last month of pregnancy, 30 goats (32.8 + 0.91 kg body weight and aged 3–4 years) were chosen and divided into three similar groups (10 goats per group). Each group was randomly assigned to be fed one of the experimental rations. The control group (R1) fed on a ration comprising concentrate feed mixture (CFM1) and berseem as a fresh roughage whereas the second (R2) and the third groups (R3) fed on CFM partially substituted by 15 and 30% of RFW (CFM2 and CFM3, respectively). Nutrient digestibility and feeding values were improved with R3 goats, which had the highest level of RFW (30%) versus R2 and R1 goats. The total volatile fatty acid (TVFA) concentration in the in-rumen liquor was elevated by increasing the level of RFW up to 30% in CFM3 of R3 goats. Actual daily milk yields were significantly ($P < 0.05$) higher (1269.30 g/h/d) for R3 goats versus R1 and R2 (1037.57 and 1180.70 g/h/d, respectively). The inclusion of RFW in rations had a significant effect on the yield of milk constituents, without significant different among experimental rations regarding some blood constituents and offspring performance. Economic feed efficiency (relative feed cost and relative daily profit) was improved by including RFW in the CFM. Therefore, it can be concluded that the inclusion of up to 30% RFW improved productive performance and economic efficiency in lactating Zaraibi goat rations.

Keywords Digestibility · Goats · Milk performance · Restaurant food waste · Rumen fermentation

Introduction

In developing countries, such as Egypt, the lack of sufficient feeds to meet the nutritional requirements of the existing animal population is one of the most critical problems in animal production problem. Unavoidable waste refers to parts of food that a human cannot eat, such as some fruit and vegetable peels, fish bones, and eggshells. However, waste that cannot be avoided can be converted into useful products as well (Lewis et al. 2017). The best way to recycle food waste to minimize pollution is to convert it into animal feed (Kim et al. 2001). The chemical treatment was effective in reducing toxic principles from sale seed meal (80–90%), neem seed cake, castor oil cake (around 100%), and Karanj cake. Water washing after chemical treatment resulted in a huge loss of dry matter. However, biological treatment with fungal culture was scressful for the safe inclusion of guar meal and rubber seed cake (Prusty et al. 2019). Inclusion of the pineapple crop waste silage is a good forage alternative for growing crossbred bull (Holstein × Gir), and include it in the diet at 2.7 times the maintenance level does not compromise growing bull performance. However, digestibility was affected by increasing level of nutrition (Mello et al. 2021). Replacing soybean meal with 0.50 and 100% soya waste (residue during the manufacturing process of tofu and soy milk from soybean in the diet of male goats (mixed bred) had no significant effect on digestibility, body weight, feed conversion, and feed cost (Rahman et al. 2020). Banana wastes (banana leaf hay and banana peel hay) had no

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significant effect on body weight gained and final weight gain for heifer (3/4 Holstein × 1/2 Zebu) in partial replacement for sorghum silage (Rigueira et al. 2021). Xue et al. (2020) found that the greater body diagonal length height at the hip, hip width, and rump length was observed by beef cattle bull fed either fresh banana by-products + rice straw or fresh banana by-products + sugar cane top. There was no variation in body weight of male goats fed diets containing spent marigold flower meal (0–30%). The nutrient digestibility was comparable, and there was no difference in biochemical parameters, except aspartate aminotransferase level was significantly higher in the treatment group (Kour et al. 2021). Therefore, dried leftover food (DLF) could be used as a supplemental feed or a feed ingredient for swine and poultry (Kim et al. 2001). This process will decrease the use of expensive feed ingredients, such as imported feeds, and reduce environmental pollution (Yang et al. 2001). Recycling excess food waste into animal feed is also economically favorable for food businesses, such as grocery stores, restaurants, bakeries, and university dining halls. Recently, the high prices of feed ingredients in the recent past have caused producers to search for alternative feed sources, such as agro-industrial by-products and fruit wastes, to reduce production costs without decreasing milk yield and quality (Ben Salem and Znaidi 2008; Romero-Huelva et al. 2017). Ruminants can convert unsuitable and unpalatable feeds into milk and meat, for humans, playing a key role in food security (Peris 2003; Moser and Lee 1992; Ryan 1988).

RFW comprises edible food waste collected from restaurants, cafeterias, and other institutes of food preparation. Therefore, processing and handling must remove all undesirable constituents, including crockery, glass, metal, string, and similar materials. Food waste can be a substitute for part of the grains and vegetable protein sources used in animal feed, which reduces the nutritional cost and competition between humans and animals (Ferguson 2020). Therefore, it is considered a wealth to fill part of the food gap. This allows the workforce to sort the food waste containing organic materials such as 1% minerals, 1% glass, 3% plastic materials, and 22% meat. The objective of this study was to evaluate the effect of partial replacement of conventional feed ingredients in the concentrate feed mixtures (CFM) of lactating goats with three levels (0%, 15%, and 30%) of RFW diets on digestibility, feed intake, blood parameters, rumen fermentation, milk yield, and composition.

Materials and methods

This study was conducted at Sakha Experimental Research Station, Kafer El-Sheik Governorate, which belongs to the Animal Production Research Institute (APRI), Agricultural Research Centre, Ministry of Agriculture, Egypt.

Preparation of restaurant food waste

Food waste was collected from restaurants as uneaten plate waste by humans, and they include food discarded after food is being served. It was collected daily for two diets (dinner and lunch) and stored then in a refrigerator. However, the undesirable materials (plastic, glass, and metals) and meats (beef, chicken, and fish) in the collected food were removed. Residual materials including (cooked rice and vegetables, hot pepper, bread, various fruits, and citrus species) were only used in animal nutrition after sun drying (Fig. 1). The restaurant food waste (RFW) was used at the rate of 0% (CFM1), 15% (CFM2), and 30% (CFM3) as illustrated in Table 1.

Feeding trial

The feeding trial was conducted using 30 lactating Zaraibi goats at third and fourth parity with life body weight of 32.8 ± 0.91 kg, and it lasted for approximately 120 days (30 days prepartum and 90 days postpartum). Goats were randomly divided into three groups (10 goats per group) using a randomized complete block design. Food was changed biweekly according to changes in weight and milk yield and goats were fed using a grouping system based on a basal ration where CFM covered 55% of NRC (2007) requirements, and berseem (fresh forage) was offered *ad libitum*. Animals were randomly allocated to undergo each tested ration: the control group (R1) received CFM1, R2 were fed CFM2 containing 15% RFW, and R3 were fed CFM3 containing 30% RFW and berseem was offered for all groups. Goats were protected from internal and external pathogens and they were kept in good health conditions and housed in pens in identical circumstances. Animals were provided with rations offered twice daily in two equal portions given at 09:00 am and 4:00 pm and freshwater was

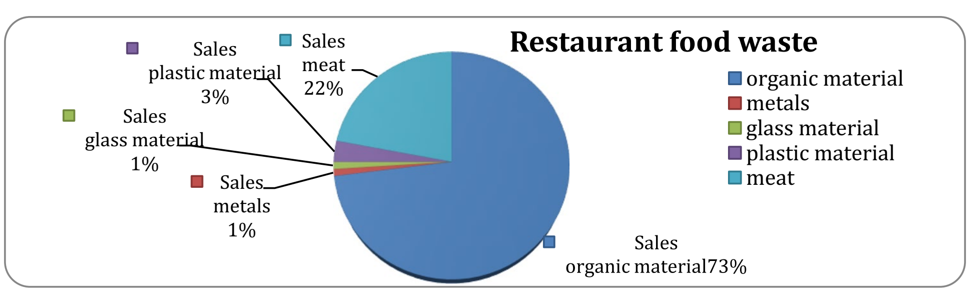

Fig. 1 Contents of restaurant food waste (RFW)

Table 1 Ingredients (%) of different concentrate feed mixtures (CFM)

	CFM1	CFM2	CFM3
RFW	-	15	30
Yellow corn	40	53	51
Wheat bran	31	10	5
Sunflower meal	20	13	5
Molasses	5	5	5
Limestone	3	3	3
Common salt	1	1	1

RFW, restaurant food waste; *CFM1* (control); *CFM2*, contained 15% RFW; *CFM3*, contained 30% RFW

available all the time. Minerals and vitamin blocks were hung in cages to allow animals to lick whenever required throughout the experimental period.

Digestibility trial and rumen liquor parameters

In the last week of the feeding trial, three digestibility trials were conducted simultaneously on the animals involved in the feeding trial (three does per group). This was done to determine the nutrient digestibility coefficients and feeding values of the tested rations using the acid insoluble ash method, according to Van Keulen and Young (1977). Feces samples were taken from the rectum twice daily within12 h intervals for 5 days, and composite samples for each animal were stored at −20°C until analysis. Samples of berseem and feces were dried at 60 °C for 72 h and however, samples of CFM, berseem, food wastes, and feces were ground through a 1-mm screen on a Wiley mill grinder. The representative samples were analyzed for dry matter (DM) content, crude protein (CP), crude fiber (CF), ether extract (EE), and ash according to AOAC (2007). Rumen liquor samples were taken via stomach tube at zero time (before feeding) and 3 and 6 h post-feeding from three animals that fed on the experimental diets. Collected rumen liquor was directly tested for pH level using a digital pH meter (Orian 680) and rumen samples were strained through four layers of cheesecloth. Ammonia nitrogen (NH_3–N) concentration was determined according to Conway and O'Mally (1942) and total volatile fatty acid (TVFA) concentration was determined according to Warner (1964).

Milk yield and milk sampling

Milk yield was recorded biweekly using the milking hand technique while the total milk yield was calculated by summation of milk over the whole experimental period. Does were completely hand milked after removing their offspring the day before to determine the milk yield until stripping the udder through two successive days during the milking period. Milk samples were directly analyzed for fat, total solids (TS), and protein (%) according to Ling (1963). Lactose (%) was determined using the method of calorimetrically according to Barnett and Abd El-Tawab (1957). Ash content was estimated according to AOAC (2007) while the solids not fat were also calculated. The value of the fat-corrected milk (FCM) (4%) was calculated according to Gaines (1928): FCM = 0.4 × milk yield (kg) + 15 × fat yield (kg).

Blood parameters

At the end of the collection period of the digestibility trial, blood samples were withdrawn from the jugular vein in heparinized tubes from each animal. The blood samples were centrifuged for 20 min. at 3000 rpm and plasma was frozen and stored at −18°C until analysis. Various chemical parameters (total protein, albumin, aminotransferase (AST), alanine aminotransferase (ALT), creatinine, and urea) were calorimetrically determined using commercial kits (Egyptian company biotechnology (SAE); following the same steps as described by the manufacturers. Plasma total protein (Armstrong and Carr 1964), albumin (Doumas et al 1971), AST and ALT (Reitman and Frankel 1957), creatinine (Folin 1994), and urea (Siest et al 1981) were determined.

Statistical analysis

Collected data were subjected to statistical analysis using SAS (2009), with the general linear model denoted as

$$Y_{ij} = \mu + T_i + {}_j + e_{ij}$$

where Y_{ij} = observation (experimental unit) taken under treatment I; μ = overall means; T_i = treatment effect (I = 1 – 3); e_{ij} = experimental error. Percentage data were subjected to arc-sin transformation to approximate the normal distribution before using analyzed data. The differences among means were statistically tested for significance at $P < 0.05$ according to Duncan (1955).

Results and discussion

Chemical composition of feedstuffs and experimental rations

The chemical composition of restaurant food waste (i.e., RFW) contained 15.64, 18.03, 9.22, 47.03, and 10.08% for CP, CF, EE, NFE, and ash, respectively (Table 2).

Table 2 Chemical composition of feedstuffs[1], concentrate feed mixtures (CFM), and tested rations (% on DM basis)[2]

	DM	OM	CP	CF	EE	NFE	Ash
RFW	96.94	89.92	15.64	18.03	9.22	47.03	10.08
Berseem	19.47	86.22	16.05	29.67	4.26	36.24	13.78
CFM1	88.39	93.00	13.75	7.97	2.86	68.42	7.00
CFM2	87.69	93.56	14.19	5.20	2.63	71.54	6.44
CFM3	88.79	92.00	15.17	6.92	3.60	66.31	8.00
Experimental rations[3]							
R1	31.30	89.57	14.91	18.95	3.57	52.14	10.43
R2	31.55	89.96	15.10	17.73	3.43	53.70	10.04
R3	31.05	89.07	15.62	18.44	3.94	51.07	10.93

[1]*DM*, dry matter; *OM*, organic matter; *CP*, crude protein; *CF*, crude fiber; *EE*, ether extract; *NFE*, nitrogen free extract. [2]*RFW*, restaurant food waste; *CFM1* (control); *CFM2*, contained 15% RFW; *CFM3*, contained 30% RFW, *R1*, CFM1 + Berseem (control); *R2*, CFM2 + Berseem; *R3*, CFM3 + Berseem. [3]Calculated

However, these results agreed with the findings of Hassanien et al. (2020), showing that the similar chemical composition of dried leftover food (i.e., DLF) was 90.38% DM, 16.78% CP, 16.50% EE, 13.52% CF, and 5.71% ash. The chemical composition of RFW reported by Kim et al. (2001) was 20–28% for CP, 10–14% for EE, 2–4% CF, and 6–12% for ash when its moisture content was below 5%. The chemical composition differences may be due to the different content of RFW. Harikumar (2001) observed a CP content of 10.25 for hotel waste. Additionally, low CP % of hotel waste might be due to the presence of cooked rice as the major ingredient of hotel waste. Cho et al. (2004) showed that the chemical composition of DLF food was 93.70% DM, 20.62% CP, 9.99% EE, 8.87% CF, and 13.67% ash. The variation in chemical composition may be due to the seasonal variability of food served in the hotel. Food waste is high in fat and ash contents. However, it is also moderately high in protein and ash (Myer et al. 1999). It is rich in most nutrients and could be used as an effective ingredient contributing as an excellent feed supplement in the rations of lactating goats. Experimental rations demonstrated some differences in their calculated chemical composition. This is due to the increased the level of RFW (up to 30%) in the tested rations, but they were almost similar for their DM, OM, CP, CF, EE, NFE, and ash contents.

Nutrient digestibility and feeding values

The inclusion of RFW in tested rations led to an improvement ($P < 0.05$) in all nutrient digestibility with R2 and R3 versus the control ration (R1). The highest digestibility values of DM, OM, CP, CF, EE, and NFE were observed with R2 and R3 goats than in the control group (R1). Moreover, the inclusion of RFW in goats' rations led to also an improvement ($P < 0.05$) in feeding values as total digestible nutrients (TDN) and digestible crude protein (DCP) versus the control group (Table 3). These results may be due to the chemical and material constituents in RFW as well as the bioactive compounds, long-chain polyunsaturated fatty acids, vitamins, carotenoids, peptides, and polyphenols are known chemical constituents of RFW. Additionally, many materials such as bread, yeast, and hot pepper that can enhance the digestive processes associated with microorganisms in the gastrointestinal tract (Newbold et al. 1990) have also been found in RFW. These results agree with those of Chae et al. (2000), reporting that the digestibility of CP and EE improved with increasing the different levels of REW in the diet of growing pigs. Ojokoh (2007) mentioned that ruminal microorganisms can play an important role in maintaining the balance between many nutrients in RFW, such as amino acids, vitamins,

Table 3 Digestibility coefficients and feeding values of experimental rations

	Experimental rations[1]			±SE[2]
	R1	R2	R3	
Digestibility coefficients[3], %				
DM	62.6^{b}	65.0^{a}	64.0^{ab}	0.58
OM	63.4^{b}	66.3^{a}	69.4^{a}	1.04
CP	69.1^{b}	70.8^{b}	78.2^{a}	0.75
CF	50.6^{b}	57.6^{ab}	62.9^{a}	2.69
EE	73.7^{b}	82.2^{a}	83.4^{a}	1.22
NFE	58.8^{b}	73.6^{a}	74.6^{a}	2.12
Feeding values[4], %				
TDN	56.5^{b}	66.8^{a}	69.3^{a}	0.91
DCP	10.3^{c}	10.7^{b}	12.2^{a}	0.11

[1]*R1*, CFM1 + Berseem (control); *R2*, CFM2 + Berseem; *R3*, CFM3 + Berseem. [2]*SE*, standard error. [3]*DM*, dry matter; *OM*, organic matter; *CP*, crude protein; *CF*, crude fiber; *EE*, ether extract; *NFE*, nitrogen free extract. [4]*TDN*, total digestible nutrients; *DCP*, digestible crude protein. a, b, and c mean in the same row for each parameter with different superscripts are significantly different ($P < 0.05$)

macroelements, and microelements. Jones et al. (1997) and EL-Husseiny et al. (2002) reported that hot pepper could be attributed to their antimicrobial, antioxidant, and improving nutrients used. Recently, dairy goats fed a diet consisting mainly of by-products in the concentrate portion exhibited improvements in nitrogen use and feed efficiency. They also produced less methane than a traditional diet containing corn and sunflower meals (Romero-Huelva et al. 2017). The incorporated by-products include concentrate, with 47% of a mixture of corn, wheat bran, sunflower meal, and soy flour (250, 50.0, 120, and 50.1 g/kg of DM, respectively). This concentrate was replaced with a mixture of tomato fruits, citrus pulp, brewer's grain, and brewer's yeast (250, 100, 70, and 50 g/kg of DM, respectively).

Rumen fermentation

All of the measured ruminal parameters of goats fed tested rations were in normal range values with different sampling, times, and they were also in the normal range values of healthy animals. There were no significant differences among experimental groups in all values of ruminal pH at 0 and 3 h post feeding (Table 4). Values of pH showed the natural distribution curve inversely, and the lowest values were at 3 h and this decrease may be due to the high fermentation of carbohydrates, increase in TVFA production (Odetokun 2000), and higher digestibility of organic matter (El-Ashry et al. 2003a). According to the natural distribution curve, the TVFA values were increased until 3 h and declined at 6 h. Higher ruminal TVFA concentration ($P < 0.05$) was observed with R2 and R3 rations than with R1 ration. This may be a result of the altered rumen population and increased microbial activity related to yeast involved in bread. These findings agree with results obtained by El-Ashry et al. (2003b) who reported that the addition of yeast culture to the rations of ruminants increased ruminal TVFA concentrations or due to bioactive compounds in spices, which have been found to possess antimicrobial, antioxidant, antiparasitic, antiprotozoal, and antifungal properties. Although, the values of NH_3–N did not differ among tested groups at all sampling times, the inclusion of RFW led to a decrease in their values at 3 h. Numerical values of ammonia-N concentrations were slightly decreased with R2 and R3 than with R1, owing to the high fermentation of carbohydrates which captured the excess ammonia into microbial protein syntheses.

Table 4 Rumen fermentation activity of goats fed different experimental rations

	Experimental rations[1]			±SE
	R1	R2	R3	
pH values				
0 h	6.71	6.62	6.75	0.06
3 h	5.65	5.56	5.53	0.12
6 h	6.21^{ab}	5.91^{b}	6.45^{a}	0.12
TVFA'S, meq/dL				
0 h	7.63^{b}	7.72^{b}	8.87^{a}	0.13
3 h	12.66^{b}	13.53^{ab}	15.05^{a}	0.64
6 h	9.87^{c}	11.55^{b}	14.00^{a}	0.33
NH_3–N, mg/dL				
0 h	12.28	13.37	13.90	1.41
3 h	31.17	29.73	28.42	2.16
6 h	17.9	19.04	19.51	2.50

[1]*R1*, CFM1 + Berseem (control); *R2*, CFM2 + Berseem; *R3*, CFM3 + Berseem. [2]*SE*, standard error. a, b, and c mean in the same row for each parameter with different superscripts are significantly different ($P < 0.05$)

Blood parameters

Plasma total proteins and albumin increased gradually from R1 to R3 with the highest value in R3 goats (7.4 and 4.10 g/dL, respectively) versus groups. In contrast, plasma AST decreased significantly ($P < 0.05$) due to increased the levels of RFW in rations (R2 and R3). However, tested groups had an insignificant effect on plasma urea and creatinine which slightly increased from R1 to R3 and this may be due to their contents of bioactive compounds contents. Generally, the collected blood constituent's data indicated that the lactating goats fed both rations containing RFW had normal physiological and healthy status. These results agreed with those of Georganas et al. (2020) who reported that bioactive compounds are substances that are present in foods in small amounts. Thus, they can provide health benefits and induce no harmful effect on liver activity (Table 5).

Table 5 Blood plasma parameters as affected by feeding experimental rations

	Experimental rations[1]			
	R1	R2	R3	±SE[2]
Total protein, g/dL	6.85	7.26	7.40	0.20
Albumin, g/dL	3.86	3.95	4.10	0.18
Globulin, g/dL	2.99	3.31	3.30	0.15
ALT, IU/L	14.84	14.51	14.89	0.22
AST, IU/L	25.51^{a}	24.11^{b}	23.87^{b}	0.19
Urea, mg/dL	7.31	7.35	7.44	0.13
Creatinine, g/dL	1.27	1.23	1.24	0.03

[1]*R1*, CFM1 + Berseem (control); *R2*, CFM2 + Berseem; *R3*, CFM3 + Berseem. [2]*SE*, standard error. a and b mean in the same row for each parameter with different superscripts are significantly different ($P < 0.05$)

Table 6 Milk yield, milk constituent's yield of goats fed different experimental rations

	Experimental rations[1]			±SE[2]
	R1	R2	R3	
Actual daily milk yield, g/h/d	1037.6[b]	1180.7[a]	1269.3[a]	29.42
4%-FCM yield, g/h/d	925.8[c]	1023.6[b]	1166.3[a]	28.82
Milk composition, %				
Fat	3.28	3.16	3.40	0.12
Protein	2.64	2.55	2.74	0.19
Lactose	3.84	3.80	4.16	0.19
Total solids	10.62	10.41	11.10	0.32
Solids not fat	7.34	7.25	7.70	0.43
Ash	0.86	0.90	0.80	0.42
Milk constituents yield, g/h/d				
Fat	34.03[b]	37.31[b]	43.16[a]	1.43
Protein	27.39[b]	30.10[a]	34.78[a]	1.71
Lactose	39.84[b]	44.87[a]	52.80[a]	1.97
Total solids yield	110.19[b]	122.91[a]	140.89[a]	4.25
Solids not fat yield	76.15[b]	85.60[a]	97.74[a]	3.29

[1]*R1*, CFM1 + Berseem (control); *R2*, CFM2 + Berseem; *R3*, CFM3 + Berseem. [2]*SE*, standard error; *FCM*, fat corrected milk. a, b, and c mean in the same row for each parameter with different superscripts are significantly different $P < 0.05$)

Milk yield, composition, and animal performance

Compared with the control goats (R1) feeding, RFW containing rations (R2 and R3) significantly ($P < 0.05$) increased the milk yield by 13.79 and 22.33%, respectively. The corresponding increase in FCM yield was 10.57 and 25.97%. The inclusion of RFW in goats' rations had no significant effect on milk composition (Table 6). These differences in production and composition of milk may be due to the higher feeding value of R2 and R3 and the different bioactive substances present in RFW (spices, fruits, etc.) that may stimulate milk production. However, the tested rations had a significant ($P < 0.05$) effect on milk constituent yields.

However, animal performance data indicated insignificant differences between the tested groups with all dams' parameters. Generally, the changes in body weight of the does did not significantly ($P < 0.05$) differ among tested groups either before or after lambing. From pre-kidding up to kidding, there was a sharp decrease in body weight for R1, R2, and R3. The sharp decrease and gain in body weight result from kidding and fetus removal and attachments. From kidding to weaning, the body weight of does increase gradually from 29.2, 32.6, and 32.4 kg at kidding, to 30.8, 32.8, and 33.6 kg at weaning for R1, R2, and R3,

Table 7 Effect of feeding different experimental rations on dams and their offspring performance

	Experimental rations[1]			±SE[2]
	R1	R2	R3	
Dams' performance				
Number of dam kidded	10	10	10	-
Initial weight at late pregnancy, kg	32.20	32.40	32.40	0.91
Body weight at parturition, kg	29.20	32.60	32.40	2.82
Body weight at 1st month after parturition, kg	23.00	25.40	25.60	2.13
Body weight at 2nd month after parturition, kg	27.00	27.80	28.60	1.69
Body weight at 3rd month before parturition, kg	30.80	32.80	33.60	1.76
Offspring performance				
Total number of kids	17	18	20	-
Litter size/ dam at birth (LSB)	1.7	1.8	2.0	-
Birth weight, kg	2.38	2.28	2.25	0.25
Weaning weight, kg	13.23[b]	13.89[ab]	14.13[a]	0.74
Total weight gain, kg	10.85	11.61	11.88	-
Average daily gain, g/ day	120.55[b]	129.00[ab]	132.00[a]	3.77
Relative improve, %	100	107.0	109.5	-
Dam production				
Litter weight at birth, kg	4.04	4.10	4.50	0.71
Litter weight at weaning, kg	22.49	25.00	28.26	2.88
Total litter weight gain, kg	18.45	20.90	23.76	-
Average daily gain, g/day	205.0	232.2	264.0	-
Relative improve, %	100	113.3	128.8	-

[1]*R1*, CFM1 + Berseem (control); *R2*, CFM2 + Berseem; *R3*, CFM3 + Berseem. [2]*SE*, standard error. a and b mean in the same row for each parameter with different superscripts are significantly different $P < 0.05$)

respectively. Accordingly, body weight and its changes were sharply decreased after kidding. Then they gradually decreased up to the 45th day of lactation subsequently began to increase, and this may be related to the stress of lactation and milk production. Kids belonging to R3 showed the highest ($P < 0.05$) weaning weight and average daily gain, being 14.13 kg and 132.00 g, respectively. Hence, it could be observed that few differences existed among the treatments regarding offspring performance measurements, especially in the birth weight of the kids (Table 7). This may be due to the very short period (only 1 month before parturition) in which dams goats start feeding on the dietary treatments. However, this very short feeding period did not considerably affect on birth weight and daily gain during the suckling period for kids and however, these results agreed with the findings obtained by Saleh (2004) and Hanafy et al. (2011), who started to feed ewes their dietary treatments approximately 1–2 months before parturition.

Feed intake, feed conversion, and economic efficiency

The results revealed that DM intake was not affected by the inclusion of RFW in goats CFM. The TDN and DCP intake (g/h/d) for goats fed RFW rations (R2 and R3) were elevated by increasing RFW in the ration *versus* control (R1) goats. These results are due to higher TDN and DCP in RFW than in the control goats. Compared with those of the control group, feed conversion as kg DM intake/kg milk and kg DCP intake/kg milk were improved with goats fed rations containing RFW and however, kg TDN intake/kg milk showed improvement only with R3, and this may be due to the increased milk yield. The relative feed cost was improved by feeding rations containing RFW, and the best improvement was observed with R3 goats. Daily profit, relative daily profit, economic, and relative economic efficiency were improved by feeding RFW containing rations (Table 8). VandeHaar and St-Pierre (2006) and Bradford and Mullins (2012) reported that feeding by-products to ruminants could decrease feed cost, improve the environmental sustainability of milk production, and support high levels of productivity if used carefully. These results are in harmony with those recorded by Paek et al. (2005), who reported that income per head was highest in the 50% substitution level of dried leftover food. Therefore, ration containing different levels of dried cafeteria leftovers was economically feasible and thus represented a cost-effective diet for pigs. Additionally, the economic return was more promising for pig-fed 67% dried cafeteria leftover containing ration (Amene et al. 2016). Moreover, Hassanien et al. (2020) reported that average daily cost/kg gain, daily profit, relative daily profit, and economic efficiency were improved by increasing dried food (20 and 40%) in crossbred cow calves' rations compared with control one.

Table 8 Daily feed intake, feed conversion, and economic efficiency

Item	Experimental rations[1]		
	R1	R2	R3
Average feed intake, g/h/d (as fed)			
Concentrate feed mixture (CFM)	800	800	800
Berseem	3690	3630	3234
Total DM intake, g/h/d	1425	1406	1339
TDN intake	805	939	928
DCP intake	147	150	163
Feed conversion			
DM intake, kg/kg (4% FCM) milk	1.54	1.37	1.15
TDN intake, kg/kg (4% FCM) milk	0.870	0.917	0.796
DCP intake, kg/kg (4% FCM) milk	0.159	0.147	0.140
Economical evaluation[2]			
Price of average daily milk, LE/dam/day	6.225	7.084	7.615
Average daily feed cost, LE/dam/day			
CFM	3.777	3.302	3.051
Berseem	0.923	0.908	0.809
Total feed cost, LE/dam/day	4.700	4.210	3.860
Relative feed cost[3], %	100	89.57	82.13
Feed cost / kg milk, L.E.	4.600	3.564	3.040
Daily profit, LE/goat/day	1.525	2.875	3.756
Relative daily profit, %	100	188.52	246.30
Economical feed efficiency	1.324	1.683	1.973
Relative improvement, %	100	127.11	149.02

[1]*R1*, CFM1 + Berseem (control); *R2*, CFM2 + Berseem; *R3*, CFM3 + Berseem. [2]Prices of concentrate feed mixtures (CFM1), (CFM2), (CFM3), and Berseem (fresh) were 4722, 4128, 3814, and 250 L.E./ton, respectively, based on the market price in 2019 and 6 LE/kg raw milk. [3]Relative cost % = the cost *f* tested ration/the cost of control ration

Conclusions

The restaurant food waste could be used as a beneficial ingredient in ration formulation for lactating goats. Studies indicated that restaurant food waste had positive effects on nutrient digestibility, milk yield and its composition, blood parameters, and economical feed efficiency. Particularly, the tested ration that contained up to 30% of restaurant food waste demonstrated a significant positive economic feed efficiency and productive performance of goats without any adverse effect.

Author contribution AMH, HAM, MHA, and YLP conceived, conducted, and designed the experiment; MMB, HAE, AAK, and AZMS did the statistical analysis and prepared the manuscript for journal submission. All authors approved the final version of the manuscript.

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Declarations

Ethics approval Animal studies have been approved by the ethical committee. The research was performed in accordance with the ethical standard laid down in the 1996 Declaration of Helsinki and its later amendments.

Competing interests The authors declare no competing interests.

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