Nutritional Quality of Bovine Cheeks Meal From Tannery Industry as a Protein Source for Monogastric Animals

Jorge Isaac Castro-Bedriñana (jcastro@uncp.edu.pe)
Universidad Nacional del Centro del Peru https://orcid.org/0000-0003-4312-6917
Doris Chirinos-Peinado
Universidad Nacional del Centro del Perú: Universidad Nacional del Centro del Peru
Flor Lizárraga-Velásquez
Universidad Peruana Los Andes
Elva Ríos-Ríos
Universidad Nacional Agraria La Molina
Rolando Quispe-Ramos
Universidad Nacional del Centro del Perú: Universidad Nacional del Centro del Peru

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Abstract

The digestibility of dry matter (DM), crude protein (CP), ether extract (EE), and the concentration of digestible energy (DE) and metabolizable energy (ME) of bovine cheek meal (CM), included in 15 and 20% were compared. The bovine cheeks not chemically contaminated, prior to the pre-tanning stage of the hides, were collected, washed, cooked, dried, and ground for their nutritional evaluation. As the CM cannot constitute 100% of the guinea pig diet, to estimate its digestibility the indigestibility coefficients of a reference diet (Barley meal-BM) were used and assuming that the indigestibility of the BM is the same in the diets with 15% and 20% CM the digestibility of CM was estimated. Twelve six-month-old male guinea pigs were used, divided into three groups of four animals per group, housed in individual metabolic cages for the total collection of urine-free feces. The DM, CP and EE digestibility's of CM-15% and CM-20% were 72.30, 95.71 and 78.34%, and 76.34, 96.03 and 82.37%, and the DE and ME contents were 4089.5, 3353.8 and 4129.0 and 3385.8 ($P < 0.05$). The results would indicate that the production of CM would be a viable option to obtain a protein meal of high nutritional value for feeding guinea pigs and could totally replace other less available and expensive protein sources, such as fish meal or soybean meal, contributing to sustainable animal production and with environmental decontamination strategies.

Introduction

A global social and moral problem to meet the food demands of population growth and the environmental sustainability of animal production is the high competition between food and feed (Herrero et al., 2015; Makkar, 2018).

Most monogastric animal diets contain soybean meal as the main source of protein (García-Rebollar et al., 2016). In the United States alone, livestock, poultry, and fish farms will consume more than 370 million tons of soybean meal in 2030, with 9 times more in the use of pesticides and causing greater deforestation for its cultivation (Pagano, 2016).

Another protein source is fishmeal, which due to its high nutritional quality (El Sayed, 2020) has become the most expensive product for animal feed; and although soybean, corn, and fish-based feeds have high nutritional value, on average, the caloric and protein efficiencies of these diets are 7–8% and lead to large energy losses (Shepon et al., 2016).

One strategy to reduce food-feed competition is to reduce the proportion of components for human use in animal feed (Schader et al., 2015) with non-conventional alternatives, such as by-products and agro-industrial waste (El Sayed, 2020; Schader et al., 2015), many of them with inadequate disposal processes that pollute the environment (Caro et al., 2014; Sivaram and Barik, 2019). These wastes, after proper processing, could be reincorporated into the production chain, making production systems more sustainable (Schader et al., 2015; Sivaram and Barik, 2019; Omoloso et al., 2021).

Among these strategies, the production of unicellular proteins has been proposed from residues, protein isolates and hydrolysates, co-products of the biofuel industry (Makkar et al., 2018), earthworm meal and other residues (Castro-Bedriñana et al., 2020), other residues from the animal industry that are incorporated into other productive subsystems must be identified, such is the case of the leather industry, which generates different residues (Kanagaraj et al., 2015; Omoloso et al., 2021). For every ton of bovine leather, 200 kg of usable leather is obtained, the waste includes 250 kg of solid waste free of contamination and without chemical products, 200 kg of tanning waste and 50 tons of wastewater (Hüffer and Taeger, 2004) that must be properly treated.

After receiving the skins, the cheeks can be obtained free of toxic substances, to be transformed into a meal with economic and environmental value as sustainable industrial practice, and reduce the negative impact of its disposal on the environment (Omoloso et al., 2021; Sivaram and Barik, 2019; Kanagaraj et al., 2015).

Bovine cheek meal can be used as a source of protein in the diets of small monogastric species such as the guinea pig, a species native to South America widely used for centuries by its population as a source of animal protein (Dunnum and Salazar-Bravo, 2010), a species that is gaining importance in the world for its lean meat, rich in protein, low in saturated fat and cholesterol, rich in calcium, iron, zinc, and vitamins of the B complex, and in several countries guinea pig blood is being used for the treatment of some classes of tumors or neoplasms since it contains the enzyme alpha asparaginase effective for the treatment of some lymphocytic leukemias (Avilés et al., 2014). Additionally, its contribution of tryptophan and phenylalanine favors the synthesis of antibodies and improves the response immune function of the body and would help in the rehabilitation of patients with various diseases, including COVID-19.

To develop scientifically balanced diets, it is necessary to know the nutritional value of feeds, so the objective of this study is to determine the proximal composition, digestibility, and metabolizable energy content of bovine cheek meals through indirect in vivo digestibility tests, comparing the effect of their inclusion at 15 and 20% in the reference diet, using adult male guinea pigs as an animal model.

Methodology

An experiment was carried out to determine the digestibility coefficients of CM included in two levels in the experimental diets. The experiment was conducted in the digestibility room of the Faculty of Zootechnics of the Universidad Nacional del Centro del Perú, located in the province of El Tambo, Huancayo-Perú (12°3'19" S, 75°13'14" W, and 3262 m a.s.l). The rehearsal room had adequate lighting, ventilation, and temperature.

In all experiments, international protocols for the care and use of research animals were taken into account (Schofield et al., 2014; Aller et al., 2020).

Pre-experimental period

The process followed was similar to that described by Castro-Bedriñana et al. (2020). For the experiment, 12 male meat-type guinea pigs of 5 months of age, with similar weights (750 g), were used, distributed in

3 groups of 4 animals each, housed in individual metabolic cages of 30 cm in diameter and 25 cm high. Each metabolic cage had its own feeder, nipple drinker, and feces collectors free from urine contamination. The number of guinea pigs per group is supported by recommendations for the care and use of research animals (Aller et al., 2020).

The pre-experimental period lasted 10 days, during which the forage (*Lolium multiflorum*) that the guinea pigs had been consuming was gradually replaced by the experimental diets plus drinking water enriched with vitamin C. At the end of this period, the guinea pigs were weighed to determine the initial weight and the supply of the experimental diets was started, monitoring the intake of feed and their corresponding faeces output.

Experimental period

The fresh cow cheeks were obtained from the "El Mantaro" tannery, Huachipa-Lima, as a by-product of the fleshing process prior to the liming stage. These cheeks are mainly made up of skin, meat, fat, subcutaneous tissue, and collagen, and are free of toxic substances. The cheek is the part of the bovine hide that covers each side of the head at the level of the neck.

Twenty kilograms of fresh cheeks were rinsed and cooked at 80°C/1 hour, then cut to approximately 3 cm^2 and oven-dried at 90°C/6 hours, and transformed into a cheek meal (CM) in a hammer mill with a sieve of 1.2 mm. The barley was also ground to the same particle size to facilitate mixing with CM.

Three diets were used for this experiment:

- Reference diet (100% BM). DM 89.0%, CP 11.8%, EE 3.5%, CF 6.1%, ME 3070 kcal/kg. With the indigestibility coefficients of this input, determined in this first trial, the CM digestibility calculations were made by the difference method.
- Experimental diet with 15% CM + 85% BM. DM 89.4%, CP 22.7%, EE 4.0%, CF 5.2%, ME 3115 kcal/kg.
- Experimental diet with 20% CM + 80% BM. DM 89.5%, CP 26.29%, EE 4.2%, CF 4.9%, ME 3130 kcal/kg.

The reference diet (BM), is the only source of nutrients in the test diet (Zhang and Adeola, 2017). Barley flour was used as a reference diet because it is a highly available and low-cost food resource in this region of the world and because as a sole feed it is readily consumed by guinea pigs (Castro-Bedriñana et al., 2020).

In the experimental period, the three diets and drinking water were administered *ad libitum* for 7 days, in which daily consumption and the corresponding urine-free fecal production were measured. At the end of this period, the guinea pigs were weighed again and the dry matter intake was calculated as a percentage of live weight and per kilogram of metabolic weight. After weighing, the guinea pigs were returned to the farm and they were gradually changed from routine feeding.

As the CM cannot constitute 100% of the guinea pig diet, to estimate its digestibility the indigestibility coefficients of a reference diet (BM) were used and assuming that the indigestibility of the BM is the same in the diets with 15% and 20% CM the digestibility of CM was estimated.

After determining the CM digestibility and energy content coefficients, the effect of the level of its inclusion on protein and fat digestibility, on digestible and metabolizable energy content, and on intake was evaluated using a completely randomized design with two treatments and 4 replicates each.

Based on the level of inclusion of CM in the digestibility tests, two treatments were used:

T1: Inclusion of 15% CM

T2: Inclusion of 20% CM

Chemical analysis, digestibility calculations, total digestible nutrients, and metabolizable energy

The DM content in feces of each guinea pig and the BM and CM samples were determined in an oven for 2 hours at 135 °C (AOAC, 2005: method 930.15) and weighed after standing for 1 hour in a desiccator. CP was determined by the Kjeldahl method (AOAC, 2005: method 954.01) using a conversion factor of 6.25. EE content was determined by the Soxhlet method (AOAC, 2005: method 991.36) and extracted with petroleum ether. Ash was determined by incineration in porcelain crucibles in a muffle furnace for 4 hours after reaching a temperature of 580 °C (AOAC, 2005: method 942.05).

Apparent digestibility coefficients of all diets were determined by the direct "*in vivo*" method according to the equation described by Zhang and Adeola (2017) and Kassa (2019):

$$D = \frac{I - F}{I} * 100$$

Where:

D: Apparent digestibility, %.

I: Nutrient ingested, g

F: Nutrient excreted, g

As the CM could not constitute 100% of the diet, to determine its digestibility, calculations were made using the indigestibility coefficients of the reference diet, thus determining the proportion of feces corresponding to the CM and estimating the digestibility of DM, CP, and EE. of the CM (Kong and Adeola, 2014). In these calculations, it is assumed that the indigestibility of BM is the same in diets with 15 and 20% CM (Kassa, 2019; Castro-Bedriñana et al., 2020). Table 1 shows an example of the mathematical calculation of the digestibility of the experimental feed.

TDN, which expresses the energy contribution of the feed, was calculated as the sum of the multiplications of the percentages of CP, EE, CF, and nitrogen free-extract for its corresponding digestibility percentages; the product corresponding to EE was multiplied by 2.25 which are the times it provides energy in relation to the other components. The sum was divided by 100 to express the TDN as a percentage. The contents of DE and ME in Kcal/kg were estimated by multiplying the percentage of TDN by 44.09, and the DE by 0.82, respectively (Weiss and Tebbe, 2019; Hales, 2019).

Statistical analysis

The level CM effect on digestibility, digestible and metabolizable energy content, and CM consumption were analyzed by ANOVA with a significance level of 0.05, using the SPSS 23 software. The correlations and regressions were also determined for the parameters evaluated with the two CM levels.

Table 1
Calculation of cheek meal digestibility by difference method. Example: guinea pig N° 05 - diet with 15% CM + 85% BM

Concept	Fresh weight, g	Dry matter	Crude protein	Ether extract
Reference feed (BM) digestibility, %*		82.64	71.39	68.61
Reference feed composition, %		89.00	11.81	3.50
Experimental feed (CM) composition, %		91.76	84.19	6.91
Nutrient intake:				
Reference feed (85%), g	127.50	113.48	13.40	3.97
Experimental feed (15%), g	22.50	20.65	17.38	1.43
Total intake	150.00	134.12	30.78	5.40
Fecal chemical analysis, %		48.00	18.02	6.12
Nutrient excreted, g	51.83	24.88	4.48	1.52
Nutrients absorbed, g		109.24	26.30	3.88
Apparent digestibility - total ration, %		81.45	85.44	71.80
Indigestibility - reference feed (BM), %		17.36	28.61	31.39
Excreted nutrients - reference feed, g		19.70	3.83	1.25
Nutrient excreted - experimental feed, g		5.18	0.65	0.28
Apparent nutrient uptake - experimental feed, g		15.47	16.73	1.15
Apparent digestibility - experimental feed, %		74.91	96.27	80.66
Digestible components - experimental feed, %		68.74	81.05	5.57
TDN - experimental feed, %		93.59		

* Mean values of dry matter digestibility, crude protein, and ethereal extract of BM correspond to *in vivo* digestibility tests in 4 male guinea pigs.

Results

Chemical composition, digestibility, and digestible components of barley and bovine cheeks meals

From 20 kg of the bovine fresh cheek, 2 kg of MC has been obtained, with a yield of 10%. The mean chemical composition of MC indicates that it has a highly digestible protein content for guinea pigs (Fig. 1).

The mean contents of DM, CP, EE, CF, NFE and ash mean contents of the BM used as a reference diet were 89.0 ± 0.04%, 11.8 ± 0.06%, 3.5 ± 0.05%, 6.1 ± 0.08%, 76.6 ± 0.03% and 2.0 ± 0.04%, respectively. The digestibility coefficients of DM, CP, EE, CF and NFE were 82.6 ± 1.5%, 71.4 ± 3.8%, 68.6 ± 10.1%, 65.3 ± 1.1% and 87.7 ± 0.9%, respectively. Their TDN, DE and ME contents were 84.99 ± 1.76%, 3747.41 ± 77.79 and 3072.87 ± 63.69 kcal/kg, respectively. The CM had between 91.74–91.77% of DM, 84.17–84.20% of CP, 6.89–6.93% of EE and between 8.90–8.91% of ash, having between 91.09–91.10% of organic matter. The CM had neither CF nor nitrogen-free extract.

Digestibility coefficients of DM, CP, EE and TDN of cheeks meal by inclusion level in total ration

The mean digestibility coefficients of DM, CP and EE of the CM were between 68.92–77.95, 94.98–96.50 and 75.36–83.67% (Table 2). Use of 20% CM significantly improved the digestibility of DM and EE of CM ($P < 0.05$).

Table 2
Digestibility coefficients of the DM, CP, and EE, digestible components, and TDN of CM by inclusion level in the experimental diets (%)

Component	15% CM				20% CM			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Dry matter digestibility	72.30[b]	2.51	68.92	74.91	76.34[a]	1.53	74.41	77.96
Crude protein digestibility	95.71[a]	0.54	94.98	96.27	96.03[a]	0.39	95.57	96.14
Ether extract digestibility	78.34[b]	2.22	75.35	80.66	82.37[a]	1.28	80.72	83.67
Digestible DM	63.34[b]	2.30	63.24	68.74	70.05[a]	1.40	68.28	71.53
Digestible protein	80.57[a]	0.45	79.97	81.05	80.84[a]	0.33	80.46	81.24
Digestible EE	5.41[b]	0.15	5.21	5.57	5.69[a]	0.09	5.58	5.78
TDN	92.76[b]	0.80	91.68	93.59	93.65[a]	0.53	93.01	94.25

[a,b] Mean values of digestibility coefficients of DM, CP, EE, and TDN by CM inclusion with different letters vary statistically ($P < 0.05$).

The inclusion of 20% of CM had a positive effect on the EE and DM digestibility improvement, with highest R^2s (Fig. 2).

DMD: Dry matter digestibility, CPD: Crude protein digestibility, EED: Ether extract digestibility, TDN: Total digestible nutrients.

Digestible and metabolizable energy content of cheek meal by inclusion level in the total ration

The 5% increase in CM had a positive effect on DE and ME for guinea pigs ($P < 0.05$) (Table 3 and Fig. 3).

Table 3
Digestible and metabolizable energy content of CM by inclusion level in experimental diets (Kcal/kg)

Energy	15% CM				20% CM			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
DE	4089.5^{b}	35.2	4042.0	4126.0	4129.0^{a}	23.0	4101.0	4155.0
ME	3353.8^{b}	28.9	3315.0	3384.0	3385.8^{a}	18.8	3363.0	3407.0

$^{a, b,}$ Mean values of digestible and metabolizable energy by CM inclusion level with different letters vary statistically ($P < 0.05$).

Digestibility and indigestibility of the rations with 15 and 20% of cheeks meal

Digestibility coefficients of DM, CP, and EE were slightly higher when using 20% of CM than when using 15% (Table 4).

Table 4
Digestibility coefficients of DM, CP, and EE by CM inclusion level in total rations (%)

Component	15% CM				20% CM			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
DM digestibility	81.04^{a}	0.39	80.5	81.3	81.35^{a}	0.32	80.9	81.7
CP digestibility	85.12^{b}	0.31	84.7	85.4	87.34^{a}	0.25	84.7	85.4
EE digestibility	71.18^{b}	0.59	70.4	71.8	73.24^{a}	0.43	72.7	73.7

$^{a, b}$ Mean values of digestibility coefficients of DM, CP, EE in total ratio by CM inclusion level with different letters vary statistically ($P < 0.05$).

The indigestibility coefficients of DM, PC and EE of the total ration were lower when including 20% of CM than when it was included in 15% (Fig. 4).

Consumption Of Cheeks Meal By An Inclusion Level (Dup: Abstract ?)

The daily DM consumption of the CM per animal during the experimental phase was 3.17 ± 0.25 grams when it was included in 15% and increased to 5.33 ± 0.04 grams when it was included in 20% ($P < 0.05$). Consumption as a percentage of live weight and per kilogram of metabolic weight ($W^{0.75}$) was significantly higher when using 20% CM (Table 5).

Figure 5 shows the regression lines and the R^2 values for CM consumption due to the 15 to 20% CM increase in the experimental diets. Determination coefficients show that more than 90% of the consumption variance is explained by the CM level inclusion, and the regression models have a fairly high fit.

Table 5
CM Consumption by CM inclusion level

CM level	CM consumption, % live weight				CM consumption, g/kg $W^{0.75}$			
	Means	SD	Min	Max	Means	SD	Min	Max
15%	0.39^{b}	0.038	0.34	0.43	20.93^{b}	1.78	18.65	22.86
20%	0.78^{a}	0.070	0.71	0.88	39.97^{a}	2.75	37.01	43.66

[a, b] Mean values of CM consumption by CM inclusion level with different letters vary statistically ($P < 0.05$).

Discussion

Chemical composition, digestibility, and digestible components of bovine cheeks meals

The CP and EE content of MC on a dry basis was above the protein content of the fish meal, blood meal, meat meal, and earthworm meal (Hussain et al., 2011; Gunya et al., 2016; Castro-Bedriñana et al., 2020), and could be a potential substitute for ingredients traditionally used as a protein source in animal diet, having to continue comparative studies at the amino acid level because the main protein in CM would be collagen) (Gauza-Włodarczyk et al., 2017).

Digestibility coefficients of DM, CP, EE and TDN of cheeks meal by inclusion level in total ration

Digestibility of the CM protein determined in this study was higher than that recorded in bovine blood meal (78.18%), donkey blood meal (87.28%), fish meal (77.31%) and was similar to earthworm meal

(94.05%) (Castro-Bedriñana and Chirinos-Peinado, 2021), which shows its high nutritional value for feeding guinea pigs.

The EE digestibility of the CM was also higher than that reported for earthworm meal (75%) and similar to that found in fish viscera meal (81%) and fishmeal (82%), and was below the values of bovine blood meal (94%) and donkey blood meal (96%) (Castro-Bedriñana and Chirinos-Peinado, 2021); variations that could be due to the quality of the protein and the presence of other micronutrients from the different inputs (Vodounnou et al., 2016). In the case of fibrous ingredients, digestibility depends on the degree of maturation and lignification of the cell wall (Hidalgo and Valerio, 2020).

The average TDN content of CM was 93.20%, a value that can be used in the formulation of rations for guinea pigs as long as the requirements and the composition of the ingredients are in terms of TDN. This average is higher than that of blood meal (73.3%), fish meal (65.3%), fish viscera meal (88.7%), and earthworm meal (86.8%) (Castro -Bedriñana and Chirinos-Peinado, 2021).

The DE of the MC was higher than that reported for bovine and donkey blood meal, fish viscera meal, fish meal, and earthworm meal (Castro-Bedriñana and Chirinos-Peinado, 2021) and may be due to the high content of EE, and the absence of crude fiber and soluble carbohydrates, because cellulose and lignified carbohydrates are known to affect digestibility mainly in monogastric (Shimada, 2015).

The digestibility of the total ration CM-20% CM was greater than in the CM-15%, an expected result due to the greater contribution and availability of proteins and fats, and the lower crude fiber content of the CM-15% diet, a result similar to those reported in other works that indicate that digestibility is higher in diets with lower content of neutral detergent fiber and with higher cellular content (Trejo-Sánchez et al., 2019; Regand et al., 2011). Brownlee (2011) demonstrated that increased dietary fiber in animals increases the viscosity of chyme in the small intestine, resulting in reduced nutrient absorption and low DM digestibility, thus reducing ED.

Use of 5% more CM allowed to increase the digestibility of DM, EE, and TDN of CM by 5.59, 5.14, and 0.96% ($P < 0.05$). The DE and ME increased by 395 and 32 kcal/kg ($P < 0.05$). The r^2 of EE digestibility coefficients, and TDN, DE, and ME contents (Figs. 2 and 3), demonstrate the positive effect of increasing the use of CM in BM-based diets by 5%. Regression equations demonstrate the importance of the inclusion level of protein sources in metabolic and digestibility studies, which improve the proportion of digestible components (Kassa, 2019), contributing to feeding use efficiency and reducing manure production, which pollutes the environment.

Consumption Of Cheeks Meal By An Inclusion Level

By increasing the level of CM from 15–20%, the consumption of CM doubled as a percentage of live weight, which responds to the better quality of the diet (Galyean et al., 2016), improving the palatability of the ration in general, showing that this input can be the main protein source of diets for guinea pigs and other small animals, as is also observed with earthworm meal (Musyoka et al., 2019).

This study shows that CM is a biotechnological resource of nutritional and ecological interest, its protein and lipid content is higher than that of other protein meals of animal origin, and due to its easy preparation and high biological value, its use in animal feed will contribute to agrifood availability through the production of small animals to contribute to food security, especially for vulnerable populations in rural areas, where most families have guinea pigs (Avilés et al., 2014).

Another important aspect of the study is its contribution to reducing competition between food and feed, and improving the efficiency of the productive ecosystem by obtaining proteins of high biological value from animal industry waste (Schader et al., 2015).

Only in Lima-Peru, there are more than 30 tanneries (50% of the country), with 70% of the total production of bovine, ovine, and goat leather, which generates more than 600 tons of solid waste free of tanning agents per year, which can enter the production chain (CITEccal-Lima, 2018).

According to our results, the uncontaminated raw residues would allow obtaining 60 tons of protein meal which, when incorporated in 15% in the diets of the animals, would allow the production of 400 tons of feed; Therefore, research has economic, environmental, and social importance and contributes to the achievement of sustainable development goals.

Study Limitations

Although we have used bovine cheeks collected prior to the liming process and have not undergone chemical additions, they could have some level of contamination from heavy metals present in the tanning industry environment. Therefore, for further studies, we recommend that heavy metal analyses be carried out to determine whether they are above the maximum permissible limits for animal feed.

Conclusions

The CM production and its incorporation into the production chain is a potential strategy to reduce the food components that do not compete with human consumption, which would allow a greater efficiency of the productive ecosystem through the transformation of the cheeks of cattle, uncontaminated waste from the tannery industry, in a flour of high biological value. Due to its high protein content and metabolizable energy, the CM is a good ingredient for feed production for guinea pigs, with potential for other monogastric animals. The guinea pigs make good use of the protein, fat and metabolizable energy of the CM when the ration contains 20% MC, being the main source of protein.

Abbreviations

DM Dry matter

CP	Crude protein
EE	Ether extract
DE	Digestible energy
ME	Metabolizable energy
BM	Barley meal
CF	Crude fiber
TDN	Total digestible nutrients

Declarations

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethics approval

The study was approved by the Specialized Research Institute of the Faculty of Zootechnics of the UNCP and the ethical guidelines for the use and care of animals in research were considered in its development.

Consent for publication

All authors approve the manuscript.

Availability of data and material

Data is included in an Excel file which is available to readers.

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Figures

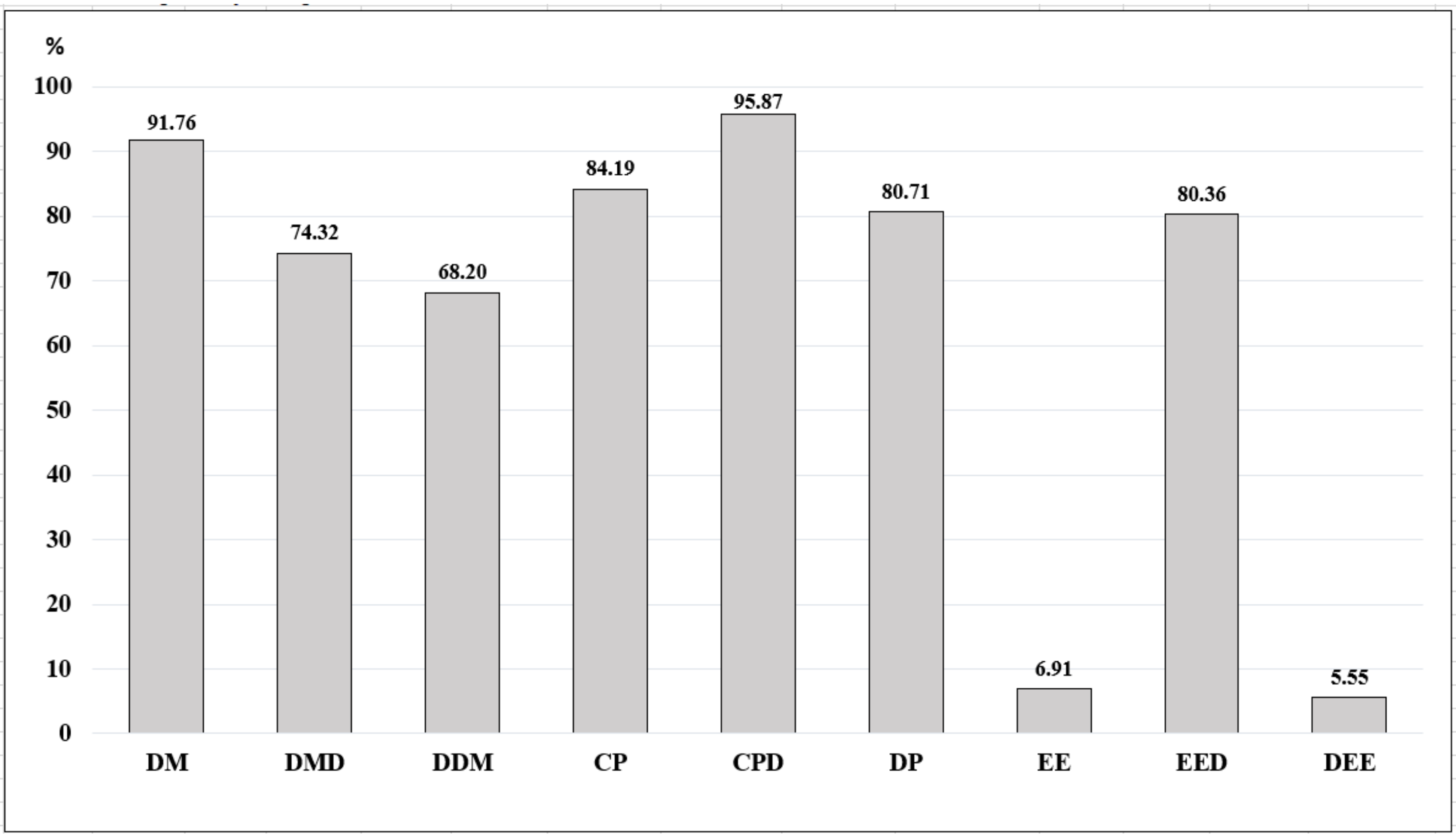

Figure 1

Composition, digestibility, and digestible components of cheek meal. DM: Dry matter, DMD: Dry matter digestibility, DDM: Digestible dry matter, CP: Crude protein, CPD: Crude protein digestibility, DP: Digestible protein, EE: Ether extract, EED: Ether extract digestibility, DEE: Digestible ether extract.

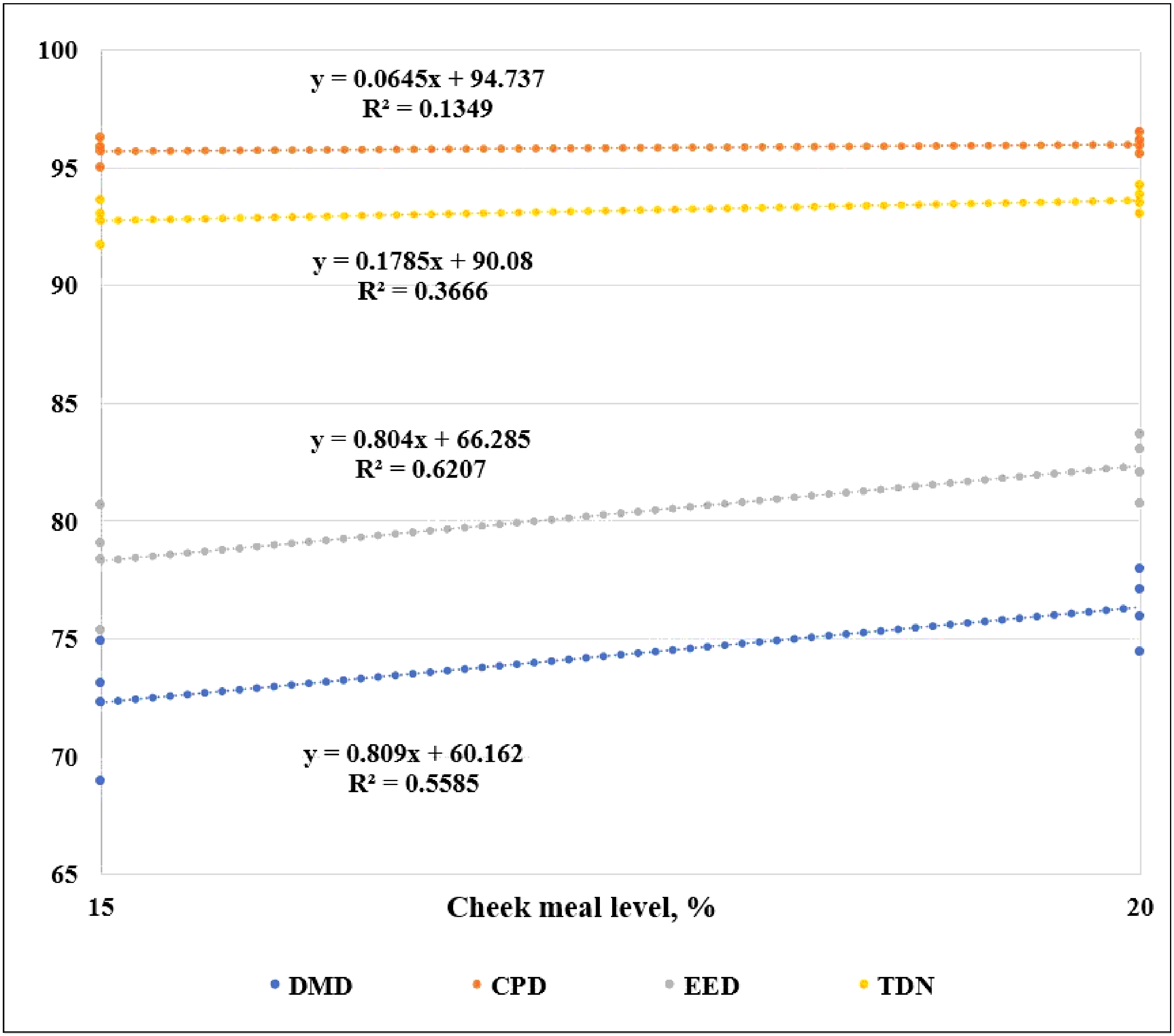

Figure 2

Digestibility coefficients trend line of the DM, CP, EE, and TDN of CM included in 15 and 20%.

DMD: Dry matter digestibility, CPD: Crude protein digestibility, EED: Ether extract digestibility, TDN: Total digestible nutrients.

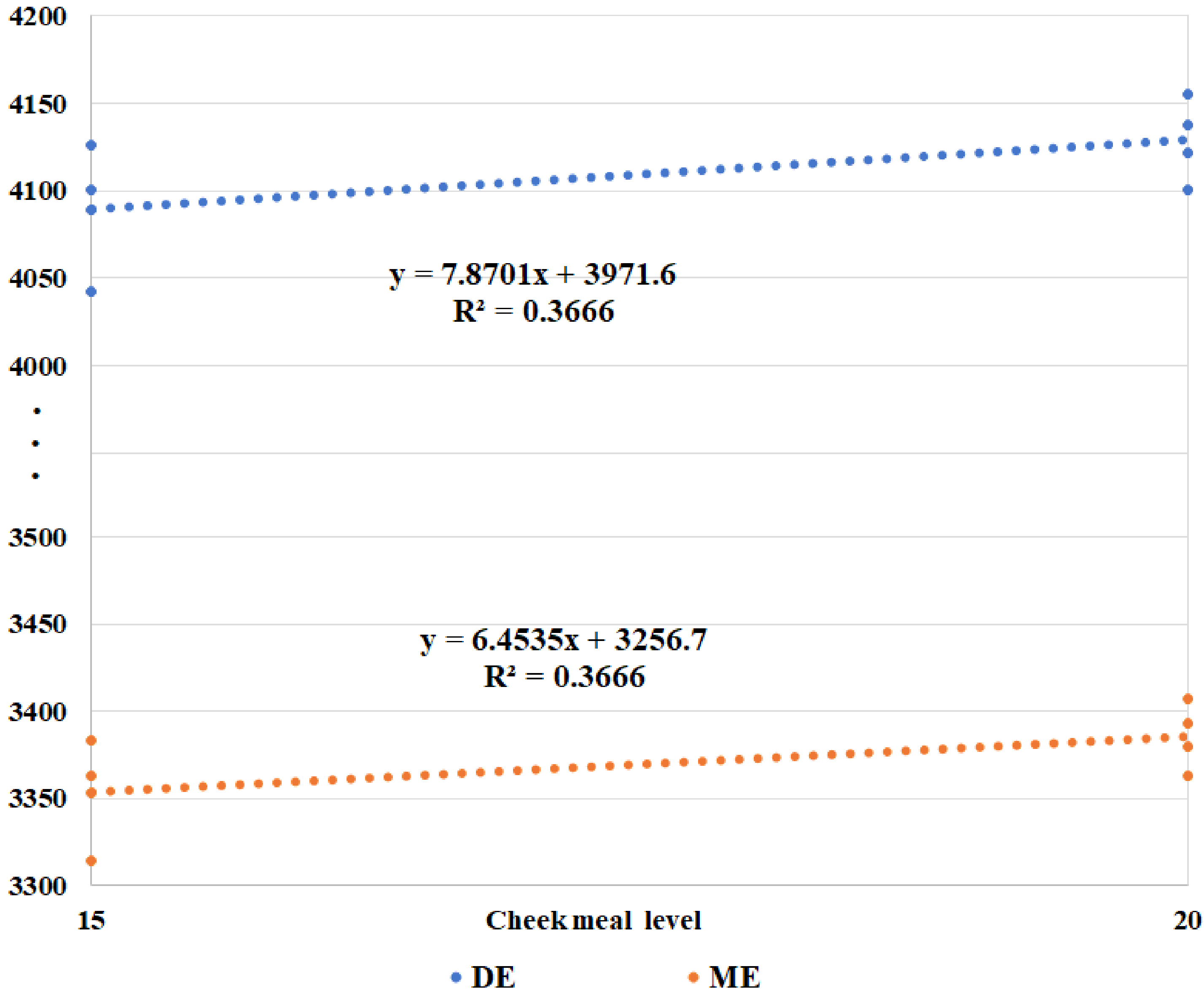

Figure 3

Digestible and metabolizable energy content trend line of CM by inclusion level. DE: Digestible energy, ME: Metabolizable energy

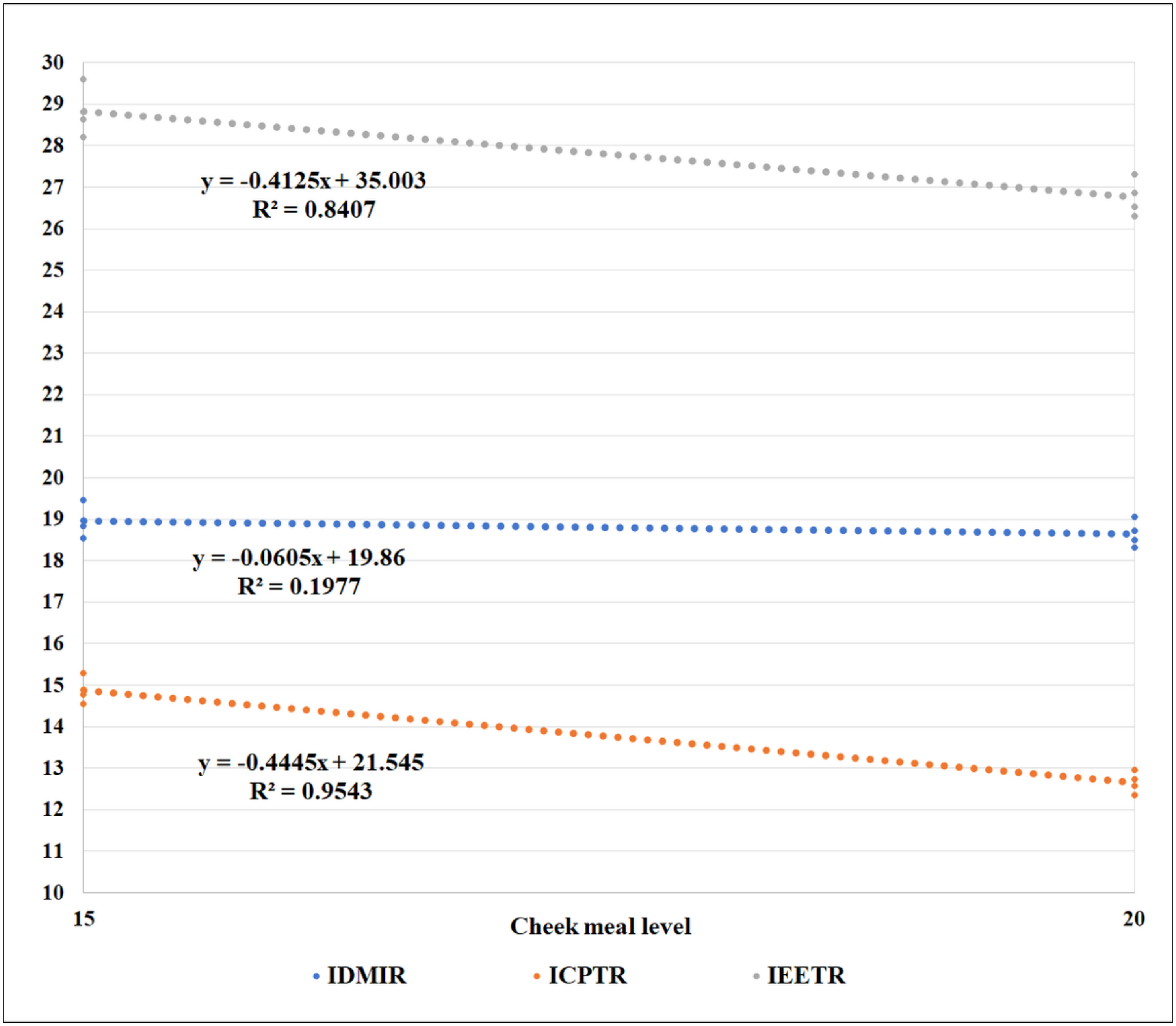

Figure 4

Indigestibility coefficients trend line of DM, CP, EE of the total ration, by CM by inclusion level. IDMTR: Indigestibility of dry matter of total ration, ICPTR: Indigestibility of crude protein of total ration, IEETR: Indigestibility of ether extract of total ration

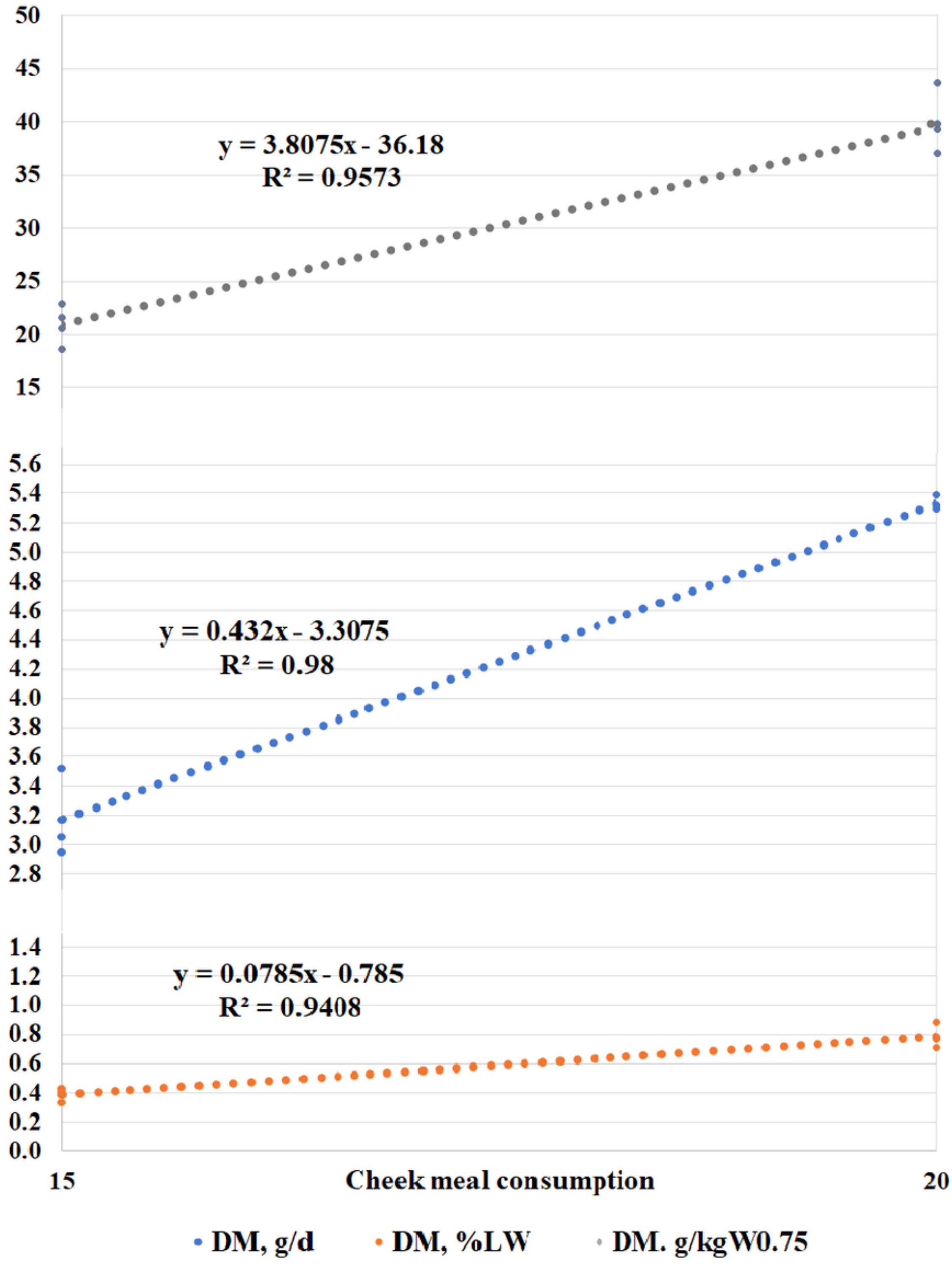

Figure 5

CM consumption in grams per animal/day, as live weight (LW) percentage, and grams/$W^{0.75}$, by CM inclusion level

Supplementary Files

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- DataSuplmaterial.xlsx