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Effect of emulsifiers on the extrusion process and sensory analysis of dry dog food

Efeito de emulsificantes sobre processo de extrusão e na análise sensorial de alimento seco para cães

Carlos Magno da Rocha Junior[1]*; Antônio Gilberto Bertechini[2]; Carla Regina Guimarães Brighenti[3]; Alexandre de Oliveira Teixeira[3]; Gabriel Cipriano Rocha[4]; Márcia Cristina Teixeira Ribeiro Vidigal[4]; Flávia Maria de Oliveira Borges Saad[2]; Leonardo Marmo Moreira[3]; Renata de Souza Reis[3]; Moara Marina Belo Matos Silveira[1]

Highlights

The use of emulsifier influences the macrostructural characteristics of kibbles.
Emulsifier use influences the texture characteristics of kibbles.
The type of emulsifier influences kibble hardness.
The use of emulsifier leads to changes in the extrusion process.
Emulsifier use decreases energy costs.

Abstract

The objective of this study was to examine the effects of emulsifying agents on processing and texture characteristics of kibbles in the pet food industry. For each treatment, four runs were performed (four replications/treatment) and four samples were collected over time. Two commercial emulsifiers, added on top of the formulation, were used in an economical extruded dry food for adult dogs, forming three treatments, namely, CON: control; EMUA: CON + 0.06% emulsifier A; and EMUB: CON + 0.06% emulsifier B. The foods were extruded in a single-screw extruder with a throughput of 6,000 kg/h, and the same set of equipment, mixing, drying, and coating conditions were adopted for all treatments. Emulsifier A contains partially saturated mono- and diglycerides, sodium stearoyl lactylate, and diacetyl tartaric acid esters of monoglycerides in its composition; whereas emulsifier B includes mono- and diglycerides of fatty

[1] PhD, Graduate Program in Animal Science, Universidade Federal de Lavras, UFLA, Lavras, MG, Brazil. E-mail: carlosmagno.rocha@yahoo.com.br; moarasilveira@hotmail.com
[2] PhD Profs., Department of Animal Science, UFLA, Lavras, MG, Brazil. E-mail: bertechini@ufla.br; borgesvet@dzo.ufla.br
[3] PhD Profs., Department of Animal Science, Universidade Federal de São João del-Rei, Campus Universitário Tancredo Neves, UFSJ, São João del-Rei, MG, Brazil. E-mail: alexandre_teixeira@ufsj.edu.br; leonardomarmo@gmail.com; carlabrighenti@ufsj.edu.br; renatareis@ufsj.edu.br
[4] PhD Profs., Department of Animal Science, Universidade Federal de Viçosa, UFV, Viçosa, MG, Brazil. E-mail: gcrbrazil@gmail.com; marcia.vidigal@ufv.br
* Author for correspondence

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acids, diacetyl tartaric acid esters of monoglycerides, and stearoyl sodium lactate. Canonical correlation analysis was performed for process correlation and kibble texture characteristics data. The multivariate lambda Wilks test was used to assess the significance of the canonical roots together. Canonical function 1 was found to be significant. There was control in the process, due to the clustering of treatments. The use of emulsifiers influenced the hardness of the kibbles, with lower resistance found in EMUA (54.731 ± 1.124) than in EMUB (121.898 ± 5.158). The EMUB treatment showed lower amperage, power, and energy consumption values than the other treatments (P<0.05). Compared with the control treatment, the EMUA and EMUB treatments showed 1.43% and 3.15% lower amperage values, respectively. In conclusion, EMUB contributes more significantly to texture characteristics and to the extrusion process.
Key words: Chewability. Factory. Kibbles. Processing. Water activity.

Resumo

Objetivou-se com essa pesquisa avaliar os efeitos de aditivos emulsificantes em características de processo e textura dos kibbles na indústria pet food. Para cada tratamento, foram realizadas quatro batidas (4 repetições/tratamento) e coletadas quatro amostras no tempo. Dois emulsificantes comerciais, adicionados on top, foram utilizados em um alimento seco extrusado, indicado para cães adultos, formando 3 tratamentos ((CON; Controle), (EMUA; CON + 0,06% emulsificante A), (EMUB; CON + 0,06% emulsificante B)). Foi utilizada dieta comercial econômica para cães adultos. Os alimentos foram extrusados em uma extrusora de rosca simples, com capacidade de processamento de 6.000 kg/h, sendo que o mesmo conjunto de equipamentos, condições de mistura, secagem e revestimento foram utilizados para todos os tratamentos. O emulsificante A possui em sua composição mono-diglicerídeo parcialmente saturado, estearoil lactato de sódio e mono éster de ácido tartárico di-acetilado, enquanto o emulsificante B possui em sua composição mono e diglicerídeos de ácidos graxos, ésteres de monoglicerídeos com ácido diacetiltartárico e estearoil lactato de sódio. Foi realizada uma análise de correlação canônica para os dados de correlação de processos e características de textura de kibble. O teste multivariado lambda Wilks foi usado para avaliar a significância das raízes canônicas juntas. Observou-se que a função canônica 1 mostrou-se significante. Percebeu-se que houve controle no processo, devido ao agrupamento dos tratamentos. A utilização de emulsificantes influenciou a característica de dureza dos kibbles, com menor resistência de EMUA (54,731 ±1,124), quando comparado a EMUB (121,898± 5,158). O tratamento EMUB obteve valores de amperagem, potência e consumo de energia inferiores aos demais tratamentos (P<0,05). Houve uma redução no valor da Amperagem, em relação ao tratamento CON de 1,43% e 3,15%, respectivamente, para os tratamentos EMUA e EMUB. Conclui-se que EMUB contribui mais significativamente para obtenção de características de textura e para o processo de extrusão.
Palavras-chave: Atividade de água. Fábrica. Kibbles. Mastigabilidade. Processamento.

Introduction

One of the ways to evaluate the palatability of a dog food is through tests that prove how the macrostructural characteristics of kibbles are influenced both by ingredients and additives, including emulsifiers. Emulsifiers are also notably used during processing to improve productivity, reducing energy costs without compromising the macrostructural characteristics of the kibble.

A number of characteristics of the food influence intake: from ingredients used in its manufacture to processing; final product quality; as well as ambient temperature, extrudate texture, and physical form (Zanatta et al., 2016).

Food emulsifiers are surface-active substances that perform various functions relating to food texture. They can enhance colloidal stability or provide controlled destabilization in emulsified or aerated food products. Interactions between emulsifiers, proteins, and carbohydrates in bakery goods or other starch-based foods improve both texture and shelf life (Chen, 2015). Emulsifiers consist of molecules and/or compounds with amphiphilic (amphipathic) properties (Bastida-Rodríguez et al., 2013) and can influence heat penetration, besides affecting the texture of the finished product (Dainton et al., 2021).

An emulsion is a suspension of one phase in a second phase, in which it is immiscible. One of the phases exists as discrete droplets suspended in the second, continuous phase, and there is an interfacial layer between the two that is occupied by some necessary surfactant material (Friberg et al., 2004). From a technological standpoint, the most important physical property of emulsions is their stability, which refers to the ability of an emulsified system to resist changes in its physicochemical properties over time (McClements, 2015). A good emulsifier keeps the droplets separated as soon as they are formed, protecting the emulsion from coalescence during prolonged storage (Araújo, 2015).

There are few published data on the possible effects of emulsifiers on food, either on nutritional characteristics (particularly ether extract digestibility and improving energy utilization) of the final extruded product (kibble) or during processing, in which they help to improve productivity, reducing energy costs without compromising the macrostructural properties of the kibbles.

In view of the above-described facts, the present study was undertaken is to examine the effects of technological emulsifying agents on characteristics of the process and texture properties of kibble in extruded dry dog food.

Material and Methods

The foods were extruded at the Planalto Alimentos company, a commercial factory located in Campo Belo - MG, Brazil.

Two mills were used during the process. The first milling procedure was performed with 3.0-mm mesh sieves (Ferraz, M-600; Ribeirão Preto, Brazil), after weighing the ingredients; and the second with 1.0-mm mesh sieves (Ferraz, M-1004; Ribeirão Preto, Brazil), after mixing the ingredients.

The foods were extruded in a single-screw extruder (Ferraz, E-200R; Ribeirão Preto, Brazil) with a 250-hp motor, throughput of 6,000 kg/h, and die diameter of 8 mm. The mixture temperature was increased by steam injection, remaining at 90 ± 3 ºC in the preconditioner and at 105 ± 5 ºC in the extruder barrel. The same set of equipment and mixing, drying, and coating conditions were used for all treatments.

After mixing for 4 min, 6000 kg of ingredients/treatment were subjected to a second milling step and packed in a metal silo. The material was transported to the agitator tank coupled to the preconditioner and thus extruded. After extrusion, the product is attracted by a pneumatic system into the dryer's distributor, which has the function of spreading the kibbles on the dryer's conveyor belt, avoiding accumulation in the corners or in the center of the belt. The two-pass conveyor dryer consisted of a drying system with heated air flow for 20 min at 130 ± 6 °C. After drying, the material was vertically cooled for subsequent application of oil and palatability enhancer in a vacuum-free coating system (Ferraz, VC-600; Ribeirão Preto, Brazil).

An economical commercial maintenance food for adult dogs (Papa Tudo Carne; Planalto Alimentos) was used.

For each treatment, four runs were performed (four replications/treatment) and four samples were collected over time (16 samples/treatment). In total, 6000 kg were used per treatment.

The ingredients were weighed and separated into silos. Before mixing, an emulsifier (EMU) from different companies (A or B) was added, forming the treatments, namely, CON: control; EMUA: CON + 0.06 % emulsifier A; and EMUB: CON + 0.06% emulsifier B. The emulsifier dose was determined following commercial inclusion suggestions. The emulsifiers were added on top of the food formulation. ulsifier A contains partially saturated mono and diglycerides, sodium stearoyl lactylate, and diacetyl tartaric acid esters of monoglycerides in its composition; whereas emulsifier B includes mono- and diglycerides of fatty acids, diacetyl tartaric acid esters of monoglycerides, and stearoyl sodium lactate.

For the analyses performed on the kibbles, samples of the final product were collected every 10 min. These consisted of 500 g for each replication (four experimental units/replication), representing a total of 16 experimental units/treatment.

The following kibble parameters were analyzed: density; moisture (Gehaka, IV2500; São Paulo, Brazil); water activity (Novasina, Lab Start-aw, Lachen, Switzerland); diameter and length, with a digital caliper (Jomarca, NCM 90173020; Guarulhos, Brazil); degree of starch gelatinization (Chiang & Johnson, 1977); and microscopy, with a binocular stereomicroscope (Coleman, ST-30 / 2I LED; Santo André, Brazil). All image analysis was qualitative and no statistical evaluation was performed.

The test to evaluate kibble texture was carried out at the Packaging Laboratory at the Department of Food Technology (DTA) of the Federal University of Viçosa (UFV), located in Viçosa, - MG, Brazil.

Twenty kibbles from each experimental unit (80 kibbles/treatment) were used in texture profile analysis (TPA), performed on a universal mechanical tester (Instron, Series

3367; Norwood, MA, USA). A 5-mm-diameter cylindrical probe was moved perpendicularly over each kibble. Operating conditions were as follows: 0.05-N load cell; compression distance of 40% of the sample height; pretest speed of 2 mm s-1; test speed of 0.5 mm s-1; and posttest speed 10 mm s-1, with two penetration cycles.

The force exerted on the sample was automatically recorded and the parameters of hardness, chewiness, gumminess, cohesiveness, adhesiveness, and elasticity were calculated automatically using Bluehill software (Instron, Bluehill 2.0; Norwood, MA, USA).

For extruder stability, the following parameters were kept fixed:

- Water entering the preconditioner = 550 L h^{-1}
- Steam pressure in the preconditioner = 3 bars
- Steam pressure in the extruder barrel = 7 bars
- Extruder Feed/Load = 38.5 Hz
- Cutting knife speed = 46.5 Hz
- Preconditioner temperature = 90 ± 3ºC
- Temperature in the extruder barrel = 105 ± 5ºC
- Dryer conveyor belt speed = 35 Hz

To assess the stability of the process, after extruder stability, extrusion amperage was checked every 2 min for 20 min, in each replication, totaling 40 readings/treatment.

Active power (kW h^{-1}) was calculated as per Carciofi et al. (2012). The obtained values were then used to calculate the energy consumption of the finished product (kWh t^{-1}).

$$\text{Active power (kW h}^{-1}\text{)} = \sqrt{\text{phase motor}} \times \text{Voltage} \times A \times \cos \phi,$$

in which √phase motor = √3; voltage = 280V; A = amperage; cos ϕ = power factor (0.86).

Canonical correlation analysis was performed for process correlation and kibble texture characteristics data. Considering the original observed data, associations were detected between the group of process characteristics (emulsifier type, density, moisture, water activity, kibble length, and kibble diameter) and a second group formed by kibble texture characteristics (degree of starch gelatinization, adhesiveness, chewability, cohesiveness, viscosity, and elasticity).

Wilks' lambda multivariate test was used to assess the significance of the canonical roots together. The Shapiro-Wilk test was used to check for the existence of multivariate normality in the data used.

Because hardness is calculated as the peak force of the first compression cycle, this variable was analyzed individually by analysis of variance and means were compared by Student's t-test at 5% probability.

All analyses were performed using R statistical software version 3.2.4 (R Core Team [R], 2018) and the CCA (González & Déjean, 2009), CCP (Menzel, 2009), and yacca (Butts, 2009) packages.

Results and Discussion

Only canonical function 1 showed significance (P<0.05). The canonical loadings for canonical function 1 are shown below (Table 1). The higher the canonical loading, the more important the variable is for deriving the canonical statistic.

Table 1
Sequences of four specific markers for bulked segregant analyses

Variables	Canonical loading
Process characteristic	
Emulsifier dose	0.64427984
Density	-0.01474916
Moisture	-0.03901769
Water activity	0.35157001
Kibble length	-0.10115027
Kibble diameter	-0.30137696
Kibble texture characteristic	
Starch gelatinization	-0.1325603
Adhesiveness	-0.6582535
Chewability	-0.7689516
Cohesion force (resilience)	0.3725095
Gumminess	-0.7544661
Elasticity	-0.6481858

Emulsifier dose correlated negatively with almost all variables. Among the characteristics of the process, kibble diameter was the most significant in module, indicating lower expansion of the kibbles. With respect to the texture characteristics, the most significant in terms of module was chewability, which, in sensory terms, means how much the animal would need to chew the food until it disintegrates, allowing for adequate swallowing. In other words, food with greater chewiness will stay in the mouth longer. Because the dog does not usually chew dry extruded food a lot, this type of characteristic can be beneficial to keep the animal feeling satiated for a longer period.

As regards moisture, the fact that the inclusion of the emulsifier allows reducing it can help both in product preservation and texture. In an experiment involving the inclusion of guar gum in wet pet foods, the addition of at least 0.5% guar gum hardened the wet pet foods and reduced moisture (Dainton et al., 2021).

In extruded dry foods, the final moisture content must be less than 10% to prevent the growth of fungi and bacteria, with water activity being a critical factor in determining the lower limit of water available for microbial growth. In general, if the water activity of a product is less than 0.65, no bacterial problems will occur, and if the water activity is less than 0.6, fungus (molds) can be avoided (Rokey et al, 2010).

There was a positive correlation between emulsifier dose and water activity, which was higher in EMUA. In practical terms, this is an undesirable characteristic, since increases to values above 0.6 are associated with greater chances of microbial development, particularly fungal development. This can cause serious harm to the animals, including death, resulting from the consumption of food with a high content of mycotoxins produced by fungi.

The correlation between the variables is illustrated next (Figure 1), where the canonical statistical variables of the canonical function are depicted in dimensions 1 and 2. As regards the distribution of samples, there was control in the process, given the grouping of treatments, with greater evidence seen for EMUA (Figure 2).

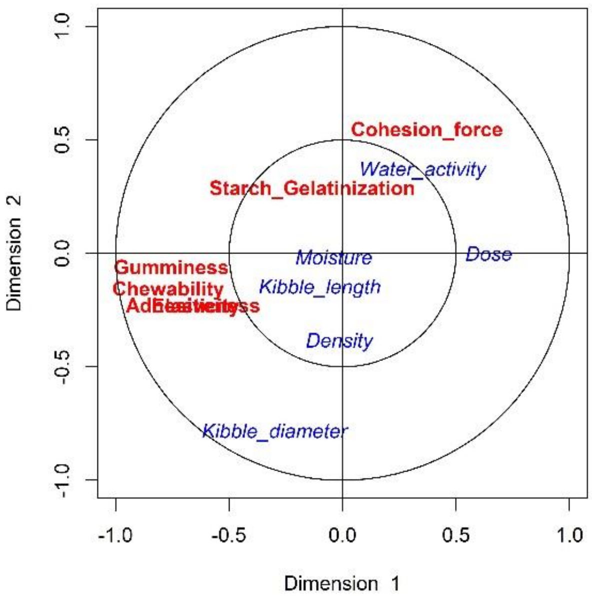

Figure 1. Canonical statistical variables.

Figure 3 illustrates internal images of the kibbles produced in the treatments. The cell structure in the treatments was compact, indicating poorly milled ingredients. Because it is an economical commercial product, this compaction is expected, since the second grinding operation was performed with 1.0-mm mesh sieves. In fact, this type of product does not use ingredients that favor expansion, such as broken rice or rice grits.

Because we did not have access to the composition of the emulsifiers regarding the amount of ingredients, the difference cannot be associated with a certain compound, since the emulsifiers have the same ingredients in their composition.

In the TPA test, the CON and EMUB treatments showed greater hardness; however, greater noise was observed during the test for the EMUB treatment. This characteristic may be a factor that reduces intake by animals, but a study on food preference must be carried out for this association to be confirmed.

Texture properties can influence the palatability of the dry food, and a greater intensity of attributes such as breakability and initial crispness can lead to greater palatability (Koppel et al., 2015).

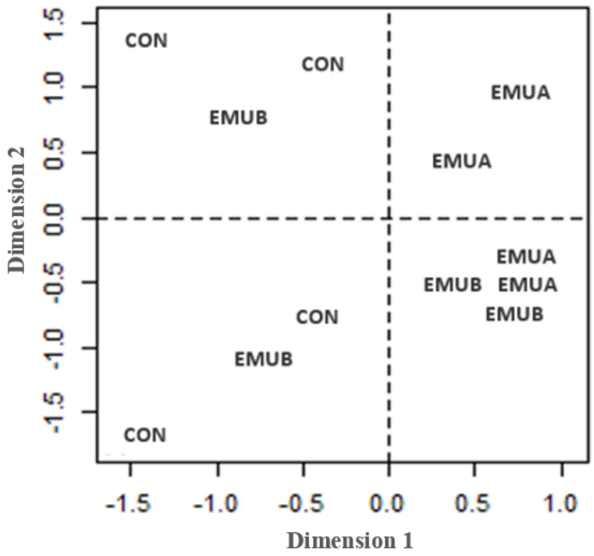

Figure 2. Sample distribution.

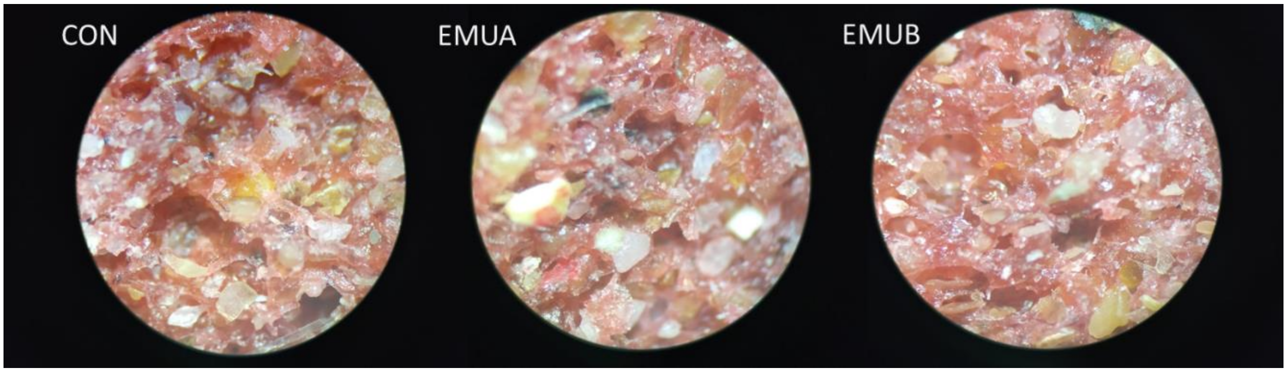

Figure 3. Binocular stereomicroscopy of kibbles produced with different emulsifiers. 25x magnification.

The use of different emulsifiers influenced ($P < 0.05$) the hardness of the kibbles (Table 2), with lower resistance found in EMUA.

Table 2
Kibble hardness

Variable	Treatment[1] CON	EMUA	EMUB	P - value	CV	R^2
Hardness	111.075 ±6.052 a	54.731 ±1.124 b	121.898± 5.158 a	0.0057	24.17	0.682

Control (CON); EMUA: CON + 0.06% Emulsifier A; EMUB: CON + 0.06% Emulsifier B.

A strong appeal regarding harder foods is related to oral health, since texture, size, and shape play an important role in the oral health of dogs and cats. There is a greater association of plaque development and gingivitis with animals that eat soft foods than with those that eat dry foods (Gawor et al., 2006).

The texture and composition of a food can directly affect the oral environment by maintaining tissue integrity, altering the metabolism of plaque bacteria, stimulating salivary flow, and cleaning dental and oral surfaces through physical contact. In short, it is believed that the physical consistency, or texture, of food affects the oral health of dogs and cats (Logan, 2006).

For the characteristics of the process, the doses and/or differences between emulsifiers could not be considered quantitative, as there are only two. Therefore, they were considered qualitative, and the test of means was performed separately.

As shown in the plot in Figure 4, amperage can be considered constant over time in all three treatments, with the lowest values detected in EMUB during the entire period of evaluation. With respect to the lower value, the reduction in amperage directly influenced the decrease in power, since it is calculated from amperage, leading to lower energy consumption by the equipment. In the industrial context, the use of emulsifiers allows for increasing the extruder load, when aiming to increase productivity. However, this action can change the texture characteristics of the kibbles.

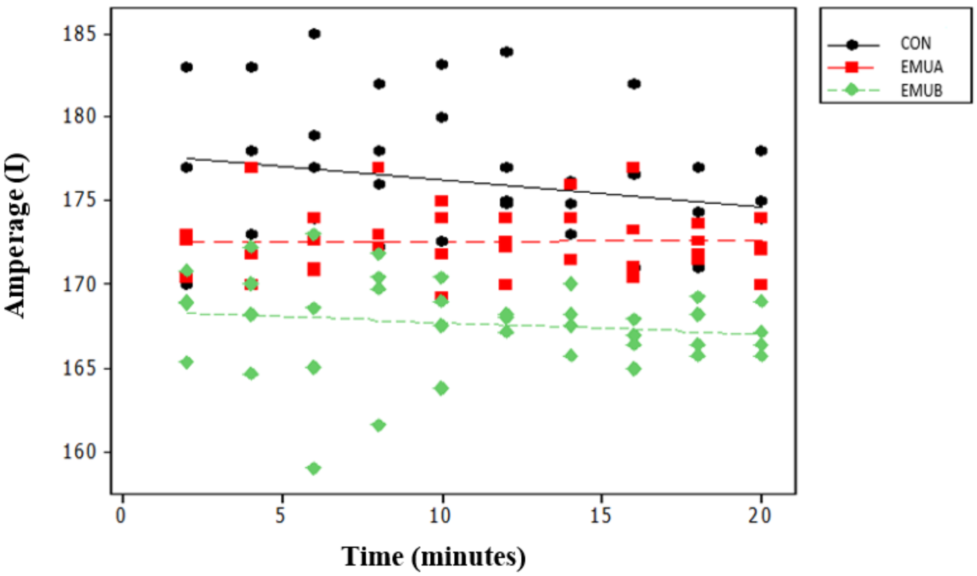

Figure 4. Evaluation of amperage as a function of time.

Since the calculations for obtaining power and energy consumption values involve amperage-dependent characteristics, the results of their evaluations and interactions are similar. Therefore, the presented results referring to amperage apply to power and energy consumption.

The interaction effects between amperage, treatments, and amperage reading time were evaluated (Figure 5). If a point is outside the decision thresholds (red dot), then there is significant evidence that the mean represented by that point is different from the overall mean.

The interaction effects were within the decision thresholds, meaning that there is no evidence of interaction between runs/replicates and the treatment. The same was observed for time, indicating control in the process. Since amperage is exclusively affected by the treatment, there is evidence that EMUB had a lower amperage value than the other treatments, at α = 0.05.

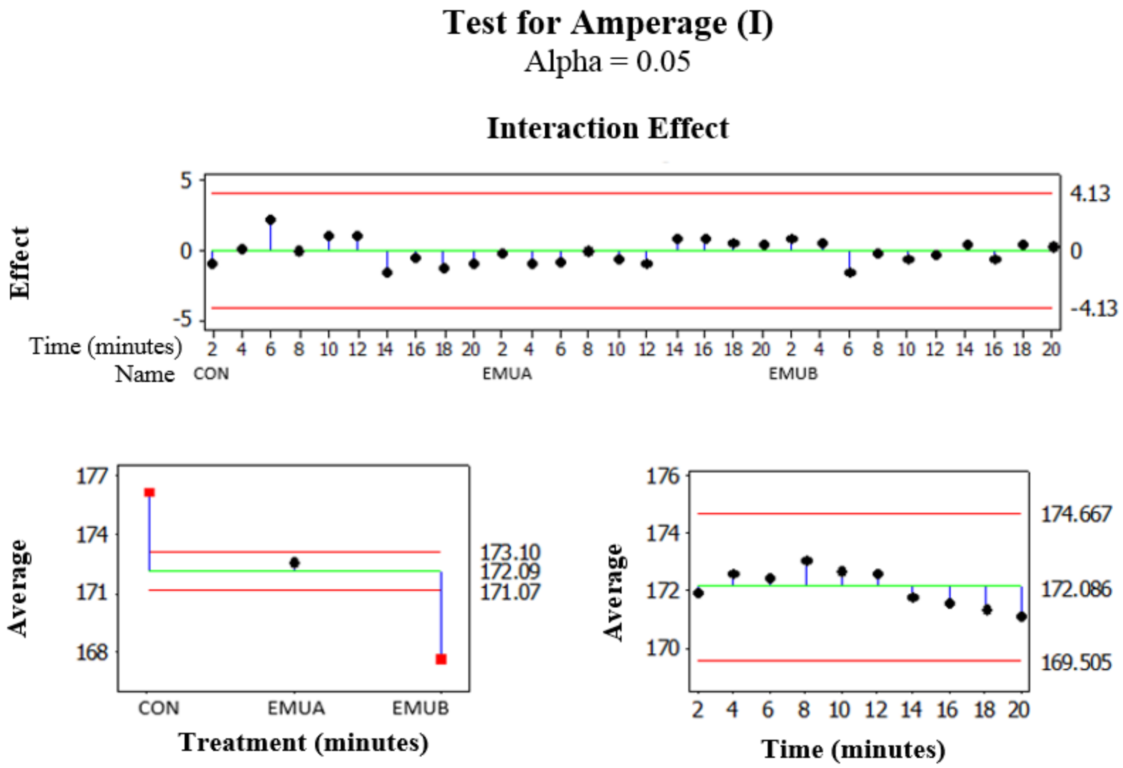

Figure 5. Interaction effect between amperage, treatments, and amperage reading time.

Conclusions

The use of technological emulsifying agents to improve the texture characteristics of kibbles and reduce energy consumption is favorable. In the present study, EMUB is indicated, which may even have a beneficial action on the oral health of animals.

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