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EVALUATION OF THE EFFECTS OF PARTIAL REPLACEMENT OF MEAT BY *TENEBRIO MOLITOR* MEAL ON THE PHYSICOCHEMICAL PROPERTIES OF MODEL MEAT SYSTEMS

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I. INTRODUCTION

Alternative proteins, such as those from insects, have gained prominence due to increasing awareness and the desire to improve the sustainability of global food consumption [Sabaghi & Sevedalmoosavi, 2025]. Yellow mealworm (*Tenebrio molitor*) is one of the most promising insect species due to its nutritional profile, and the development of hybrid meat products with this insect may contribute to greater acceptance of products with alternative protein sources. Therefore, the study investigated the impact of replacing lean meat with whole tenebrio (*Tenebrio molitor*) flour on the physicochemical properties of model meat systems.

II. MATERIALS AND METHODS

Metamorphosis (Brazil) provided the whole tenebrio flour (*Tenebrio molitor*), object of study of a broad thematic project "Insect Proteins: New Ingredient for the Food Industry (PROTINA nº 01.23.0776.00). The meat model systems were processed in triplicate. Three treatments were prepared with 15 and 30% replacement of lean meat by whole *Tenebrio molitor* flour (TMF), F1 and F2, respectively, in addition to the control (FC) with 65% pork. All treatments had 20% pork back fat, 13.3% ice, 1.5% sodium chloride, 0.015% sodium nitrite, 0.16% cochineal carmine dye, and 0.05% sodium erythorbate. For the preparation of all treatments, the ground pork (5 mm disc), together with the salt and part of the ice, was homogenized in a food processor at 1000 rpm for 40 seconds, followed by the addition of additives, tenebrio flour (F1 and F2) and homogenization at 2000 rpm for 1 minute or until the maximum limit of 12ºC.Two hundred grams of each treatment were placed in a polyethylene bag and cooked in a water bath at 75ºC for 30 minutes. The samples were then cooled on ice and stored at 4ºC. The emulsion stability of the meat was determined according to the method of Hughes et al. (1997). Texture profile analysis (TPA) was evaluated (25 ºC) in a TA-xT2i texture analyzer, with twelve cylinders (20 mm) that were axially compressed (2 cycles of 30% compression, probe P35) at a constant speed of 1 mm/s. The pressed juice of the samples was determined according to the methodology described by Lucherk et al. (2017). The parameters evaluated were hardness (N), springiness, resiliency, cohesiveness, and chewiness (N). The color was analyzed using a CM-5 spectrophotometer (Konica Minolta, Tokyo, Japan), operating with a D65 illuminant, a 10° observation angle, RSEX mode, and the CiELab color system to determine the L*, a*, and b* parameters, in addition to the whiteness index. The results were assessed using analysis of variance, using Statsoft. Inc. version 7 software (TIBCO Software Inc., California, USA). Tukey's test ($P < 0.05$) was used to determine significant differences between treatments.

III. RESULTS AND DISCUSSION

Tenebrio flour considerably influenced the textural parameters (Figure 1). Adding TMF increased the firmness, chewiness, and springiness values compared with the control treatment. Opposite results were found by Zhang et al. 2022 when partially replacing lean meat with *Tenebrio molitor* flour (10 and 15%) in Frankfurters, with lower firmness values. These authors used dehydration methods (lyophilization and microwave) that were different from those of this study (conventional oven with air circulation), affecting the proteins' functional properties. The Table 1 shows the emulsion stability and pressed juice of the samples. Regarding the results found for pressed juice, significantly higher values ($P<0.05$) were observed in treatments F1 and F2 than FC, showing that a greater release of liquid occurs when an external force is applied to the meat model systems. The higher juiciness values found in the reformulated treatments indicate that the release of fluids from the model systems exhibits different behavior depending on the nature of the external force applied: standardized pressure in the juiciness tests or heating in the case of the emulsion stability test. The luminosity (L*) and a* values decreased proportionally with

the increase in mealworm, and b* increased in the treatments F1 and F2 (Table 2). Zhang et al. (2022) also demonstrated that adding yellow mealworm resulted in frankfurters' darker and yellower color.

Table 1 – Emulsion stability and pressed juice of model meat systems prepared by replacing of lean meat with TMF

Parameters	FC	F1	F2
Emulsion stability			
% Stability	90.03±0.64^{c}	98.47±0.24^{b}	99.46±0.39^{a}
Liquid released (%)	3.92±0.25^{a}	0.56±0.09^{b}	0.15±0.15^{c}
Fat released (%)	0.26±0.00^{c}	0.36±0.00^{b}	0.41±0.00^{a}
Pressed juice (%)	17.06±0.47^{b}	23.03±0.45^{a}	24.23±0.60^{a}

* The values represent the mean ± standard deviation. ^{a,b,c,d} Means in the same row with different letters indicate significant differences ($P < 0.05$).FC: treatment control with 65% lean meat; F1 and F2: 15% and 30% replacement of lean meat by TMF, respectively.

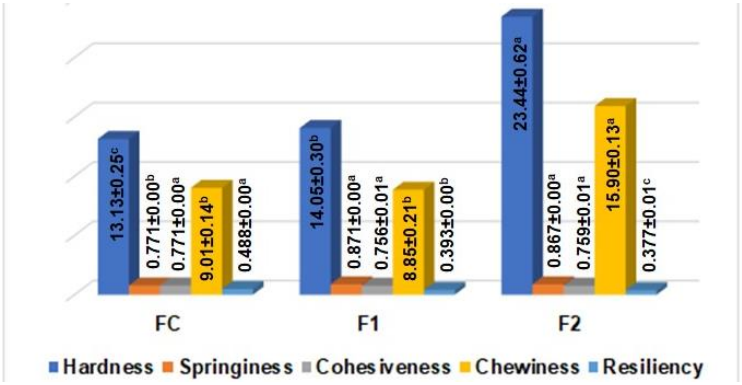


Figure 1. Texture of model meat systems prepared by replacing different ratios of lean meat with whole *Tenebrio molitor* flour. FC: treatment control with 65% lean meat; F1 and F2: 15% and 30% replacement of lean meat by TMF, respectively.

Table 2- Color parameters of model meat systems prepared by replacing different ratios of lean meat with TMF

Color parameters	FC	F1	F2	Appearance
L*	71.66±0.12^{a}	64.05±0.14^{b}	59.31±0.34^{c}	
a *	14.34±0.12^{a}	9.99±0.11^{b}	8.45±0.03^{c}	
b *	5.51±0.04^{c}	11.45±0.04^{b}	13.07±0.10^{a}	
Whiteness	67.77±0.12^{a}	60.97±0.14^{b}	56.43±0.30^{c}	

* The values represent the mean ± standard deviation. ^{a,b,c,d} Means in the same row with different letters indicate significant differences ($P < 0.05$). FC: treatment control with 65% lean meat; F1 and F2: 15% and 30% replacement of lean meat by TMF, respectively.

IV. CONCLUSION

Replacing up to 15% of lean meat with whole Tenebrio molitor flour may be a relevant strategy for producing a hybrid meat emulsion with adequate physicochemical properties. However, technological challenges remain, such as interference in color.

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