CAN IRRADIATION INFLUENCE THE PHYSICOCHEMICAL PROPERTIES OF HYBRID BEEF BURGERS WITH *TENEBRIO MOLITOR*?

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I. INTRODUCTION

The environmental costs of traditional proteins drive the search for sustainable alternatives. *Tenebrio molitor* is one of the most promising edible insect species, offering high protein content with reduced environmental impact. In line with sustainable options, technologies such as irradiation provide numerous advantages, such as speed, safety, low cost, and environmental friendliness. It has been shown that irradiation can change the physicochemical properties of flours, such as wheat flour [Shen et al., 2024]. However, to the best of our knowledge, the impact of irradiation treatment on the physicochemical properties of insect flours, such as *Tenebrio molitor*, and products reformulated with this ingredient remains unexplored. Therefore, this study investigated the effects of γ-irradiation (0, 2.5, 5.0, and 7.5 kGy) on the physicochemical properties of beef burgers with partial replacement of lean meat by irradiated mealworm flour.

II. MATERIALS AND METHODS

Tenebrio molitor larvae were slaughtered at 70 days of age by Metamorphosis Biotechnology (São Paulo, Brazil), after 24 h of fasting with a source of moisture *ad libitum*, followed by cooling to 7ºC (24h) and slaughter by freezing (24h). The larvae were dehydrated in a dehydrator with air circulation for 12h at 50ºC. The dehydrated insects were processed in an industrial blender, and the flour granulometry was standardized on 20 mesh screens.The γ-irradiation treatment of the mealworm flour was performed at the Institute of Energy and Nuclear Research (IPEN) (São Paulo, Brazil) and subjected to a ^{60}Co gamma irradiation at room temperature. The irradiation doses of 0 (non-irradiated, used as control), 2.5, 5.0, 7.5 kGy, with a dose rate of 1 kGy/h, were given. Five treatments were prepared for the processing of the burgers, four with 20% replacement of lean meat by Tenebrio molitor whole meal (TMF) with different irradiation doses, respectively T0kGy, T2.5kGy, T5.0kGy, and T7.5kGy, in addition to a control treatment (TC) with 66% beef. All treatments had 1.15% spices, 1.6% sodium chloride, 0.05% sodium erythorbate, 0.3% sodium tripolyphosphate, and 12.18% cold water. The burgers were prepared according to Essa & Elsebaie [3]. The TMF flours were characterized according to instrumental color and water and oil retention capacities (WRC and ORC), which were determined according to Kabirullah and Wills (1982). The burgers' technological properties (cooking losses, shrinkage) and instrumental color for raw and grilled samples were determined (Konica Minolta CM-5 spectrophotometer colorimeter in the CIELAB color system). Texture profile analysis (TPA) was evaluated (25 ºC) in a TA-xT2i texture analyzer, with twenty-four cylinders (20 mm) that were axially compressed (2 cycles of 40% compression, probe P36) at a constant speed of 1 mm/s. The parameters were evaluated hardness (N), springiness, cohesiveness, and chewiness (N). The results were assessed using analysis of variance (ANOVA) with general linear models, using Statsoft. Inc. version 7 software (TIBCO Software Inc., California, USA). Tukey's test at 5% significance level ($P \leq .05$) was used to determine significant differences.

III. RESULTS AND DISCUSSION

Table 1 shows the characterization results of mealworm flours with different doses of gamma irradiation. The doses of 2.5 and 5.0 kGy provided technological benefits to the flours, improving their water retention capacity and making them lighter. Figure 1 shows the effects of reformulation on color parameters and the appearance of the products. Regarding the raw samples, the T5kGy treatment was equal to the control for the brightness parameter, once again indicating the ability of irradiation to promote sample whitening. However, higher irradiation doses (7.5kGy) left the raw samples more yellow, which may indicate oxidative processes. The 2.5kGy dose demonstrated better results for the grilled samples, and T2.5kGy did not differ from TC for the L* and a* parameters.

Table 1 – Characterization of TMF with different irradiation doses.

* The values represent the mean ± standard deviation. [a,b,c]Means in the same row with different letters indicate significant differences (P < 0.05).

Treatments	L*	a *	b *	ΔE	Appearance	WRC (mL/g sample)	ORC (mL/g sample)
TOkGy	45.91±0.69^{c}	6.47±0.04^{a}	25.21±0.79^{a}	__		1.83±0.08^{c}	1.79±0.11^{a,b}
T2.5kGy	50.56±0.49^{a}	6.14±0.18^{a}	25.53±0.53^{a}	4.69±0.52^{a}		2.05±0.07^{a,b}	1.92±0.05^{a}
T5.0kGy	48.73±0.64^{b}	6.43±0.34^{a}	25.69±0.30^{a}	2.88±0.63^{b}		2.10±0.11^{a}	1.85±0.04^{a,b}
T7.5kGy	46.45±0.57^{c}	6.08±0.28^{a}	26.39±0.86^{a}	1.51±0.69^{b}		1.96±0.06^{b}	1.74±0.22^{b}

Figure 1. Color parameters of raw and grilled samples of burgers reformulated with TMF and different irradiation doses.

Regarding the technological properties of the products (Table 2), lower cooking losses and shrinkage were achieved at T7.5kGy, which differed from the others (P<0.05). Texture results showed that doses of 5 kGy left the burgers significantly firmer and with greater chewiness (P<0.05) than the others. TC was the most cohesive and elastic, which was expected due to the functional properties exerted by myofibrillar proteins.

Table 2 – Characterization of TMF with different irradiation doses.

	TC	T0kGy	T2.5kGy	T5.0kGy	T7.5kGy
Textural parameters					
Hardness (N)	15.89±0.88^{d}	22.68±0.97^{b}	23.75±0.52^{b}	26.12±0.78^{a}	21.15±1.09^{c}
Springiness	0.836±0.00^{a}	0.775±0.01^{c}	0.798±0.01^{b}	0.793±0.00^{b}	0.827±0.01^{a}
Cohesiveness	0.741±0.00^{a}	0.678±0.01^{d}	0.690±0.01^{c}	0.685±0.01^{c,d}	0.701±0.01^{b}
Chewiness (N)	9.51±0.44^{d}	12.51±0.30^{b}	12.64±0.33^{b}	14.25±0.59^{a}	11.80±0.40^{c}
Technological parameters					
Cooking losses (%)	25.50±1.33^{a}	10.13±1.16^{b}	11.37±1.02^{b}	11.11±1.24^{b}	5.75±1.08^{c}
Shrinkage (%)	17.39±1.28^{a}	9.67±1.34^{c}	14.32±0.59^{a,b}	11.77±1.24^{b,c}	9.14±1.03^{c}

* The values represent the mean ± standard deviation. [a,b,c]Means in the same row with different letters indicate significant differences (P < 0.05).

IV. CONCLUSION

This study demonstrated that irradiation technology influences the physicochemical properties of *Tenebrio molitor* flour and reformulated products with this ingredient. Numerous benefits in its application should be investigated in greater depth.

ACKNOWLEDGEMENTS

The authors would like to thank Financier of Studies and Projects (FINEP) (PROTINA nº 01.23.0776.00) for their financial support and the UFVJM for granting the use of the texturometer.

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