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REFRIGERATED STORAGE OF HYBRID BEEF PATTIES WITH *TENEBRIO MOLITOR* FLOUR AND ITS EFFECT DURING GRILLING

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I. INTRODUCTION

To ensure global food security for a growing population, edible insects have emerged as a viable source of high-quality protein due to their efficient feed conversion and low environmental impact [1]. Incorporating insect flour into hybrid meat products is a promising strategy to promote the consumption of this alternative protein source [2]. This study evaluates the effect on the technological properties of grilled hybrid beef patties where lean beef were replaced with T. molitor flour at different levels (5.0%, 7.5%, and 10.0%) and kept refrigerated (6 days) before cooking.

II. MATERIALS AND METHODS

Four formulations of hybrid beef patties were prepared: Control (86.5% beef, 10.0% water/ice, 2.0% onion powder, and 1.5% NaCl), and HT50, HT75, and HT100, with 5%, 7.5%, and 10% of beef replaced by *T. molitor* flour. Beef and half of the ingredients were homogenized (Hobart N50 6, Troy, OH, USA) for 1 min. The remaining half was added and homogenized for 1 minute, followed by a final 1-minute mixing. Portions (90 g) were shaped using a patty mold, vacuum-sealed in polyethylene bags, and stored at 4 °C for analysis the following day. The final proximate composition of beef patties was: 66.22–72.46 g/100 g moisture, 19.31–22.99 g/100 g protein, and 5.96–6.63 g/100 g fat. On each analysis day, patties were grilled on a preheated (180 ºC) electric grill (JATA GR3000, Spain) for 6 minutes. Color was measured 10 times per sample using a CM-5 spectrophotometer (Konica Minolta, Japan) with a D65 light source, 10° standard observer, and 8 mm aperture. CIELAB parameters (L^*, a^*, b^*) were recorded, and the total color difference (ΔE^*) related to the Control was calculated. Kramer Shear Force (KSF) was performed 5 times on grilled patties using a Kramer (HDP/MK05) cell in a TA-XTplus Texture Analyzer (Stable Micro Systems Ltd., Godalming, UK) equipped with a 25 kg load cell. A mini 5-bladed head was used to conduct the shearing test. Samples measuring 2 × 2 cm were cut, weighed, and placed into the cell at room temperature. A force was applied to a compression distance of 20 mm at 0.8 mm/s crosshead. KSF values were calculated as the maximum force per gram of sample (N/g). Statistical analysis was performed using a two-way ANOVA, and Tukey's HSD test assessed mean differences at a significance level of $p \leq 0.05$.

III. RESULTS AND DISCUSSION

Grilled hybrid beef patties showed significantly lower ($p \leq 0.05$) L^*, a^*, and b^* values as the proportion of *T. molitor* flour increased on day 1 of storage (Table 1). This effect is also evident (Figure 1), indicating that adding dark protein sources results in patties with a visibly darker appearance. Similar behavior has been reported in beef patties with *Acheta domesticus* [2] and *Alphitobius diaperinus* [1] flours. Overall, HT75 and HT100 demonstrated greater stability in L^*, a^*, and b^* during storage, with no significant differences between days 1 and 6. Nevertheless, ΔE^* values (Table 1) exceeded 5, confirming perceptible color differences [4] between HT75 and HT100 compared to Control, which was not observed in HT50.

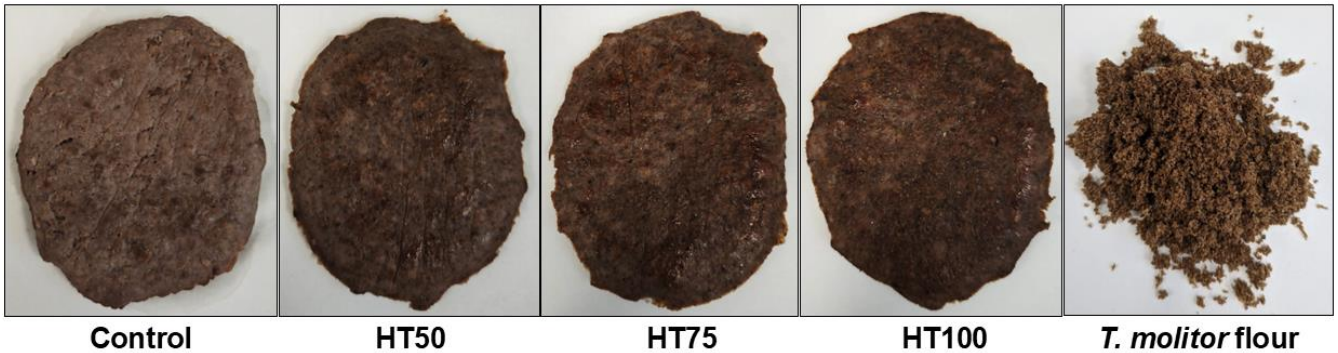


Figure 1 - Appearance of grilled hybrid beef patties with *T. molitor* flour.

Table 1 – Color parameters and KSF of hybrid beef patties with *T. molitor* flour during storage and their effect during grilling.

Parameter	Day	Treatment			
		Control	HT50	HT75	HT100
*L**	1	47.3 ± 0.9^{Ba}	45.2 ± 2.0^{Bab}	44.2 ± 1.9^{Abc}	42.7 ± 1.5^{Ac}
	6	53.0 ± 0.7^{Aa}	48.7 ± 2.2^{Ab}	45.9 ± 1.6^{Ac}	44.5 ± 1.7^{Ac}
*a**	1	5.0 ± 0.6^{Aa}	4.7 ± 0.5^{Aa}	4.0 ± 0.6^{Ab}	3.9 ± 0.4^{Ab}
	6	4.2 ± 0.3^{Ba}	4.0 ± 0.5^{Ba}	3.7 ± 0.3^{Aa}	3.6 ± 0.6^{Aa}
*b**	1	9.5 ± 1.1^{Aa}	8.3 ± 0.8^{Ab}	8.0 ± 0.3^{Ab}	7.3 ± 1.0^{Ab}
	6	8.3 ± 0.5^{Bab}	8.8 ± 0.4^{Aa}	7.6 ± 0.6^{Abc}	7.0 ± 0.9^{Ac}
ΔE^*	1	-	3.2 ± 1.8^{Aa}	4.2 ± 1.0^{Ba}	5.5 ± 1.8^{Ba}
	6	-	4.5 ± 2.4^{Ab}	7.2 ± 1.9^{Aa}	8.8 ± 2.2^{Aa}
KSF (N/g)	1	29.38 ± 1.22^{Aa}	26.88 ± 1.02^{Ba}	28.68 ± 1.02^{Ba}	30.32 ± 1.68^{Ba}
	6	32.86 ± 1.05^{Ab}	34.92 ± 2.85^{Ab}	42.45 ± 2.50^{Aa}	43.34 ± 0.54^{Aa}

Means ± standard deviation. Different uppercase superscripts (A–B) in the same column indicate significant differences ($p \leq 0.05$) within the same treatment over the storage period. Different lowercase superscripts (a–d) within the same row indicate significant differences ($p \leq 0.05$) among treatments on the same day. Control: 0% *T. molitor* flour; HT50: 5% *T. molitor* flour; HT75: 7.5% *T. molitor* flour; HT100: 10% *T. molitor* flour.

KSF values were similar ($p \geq 0.05$) among treatments on day 1, ranging from 26.88 to 30.32 N/g (Table 1). By day 6, HT75 and HT100 exhibited significantly higher values ($p \leq 0.05$) than HT50 and Control. Overall, treatments containing *T. molitor* flour showed a significant increase ($p \leq 0.05$) in shear force during storage. Increased shear resistance has also been reported in patties enriched with insect flour [1, 2], often associated with lower moisture content and a denser structure. Nevertheless, the HT50 result on day 6 did not differ ($p \geq 0.05$) from Control, indicating the feasibility of incorporating this level of insect flour into hybrid beef patties.

IV. CONCLUSION

Incorporating *T. molitor* flour at 7.5% and 10% affected the color and texture of grilled hybrid beef patties, resulting in darker and firmer products compared to Control. In contrast, partial substitution of beef with *T. molitor* flour at 5% did not compromise the color or texture, supporting its feasibility as an alternative protein source for the preparation of grilled hybrid patties.

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