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ORIGINAL RESEARCH PAPER

CRICKET POWDER *(ACHETA DOMESTICA)* AS FOOD ADDITIVE FOR PROCESSING OF DRY-FERMENTED POULTRY BARS

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Abstract: In the recent years crickets, as well as cricket powder (CP) are interesting food ingredients in the European market. Some benefits of CP are high content of quality proteins, fats, vitamins and minerals and little environmental footprint. The aim of this work was to explore the impact of CP additive (2 and 4 %) on the color characteristics, technological and sensory properties of dry-fermented poultry bars. The use of CP as meat additive significantly decreases L* and a* values of the product. Structural strength, plastic strength and *p*H were significantly increased ($p < 0.05$) in CP enriched raw and dry-fermented poultry bars. The moisture content and water activity (a_w) in the final CP enriched poultry products increased ($p < 0.05$). The incorporation of 2 % CP had slight impact on sensory properties of final product and can be successfully used for processing of value-added meat products. CP addition up to 4 % had negative effect on the color, sensory properties, structural and plastic strength on the filling mass and dry-fermented meat bars.

Keywords: *edible insects, novel protein, poultry meat, processing, sensory characteristics*

INTRODUCTION

Insects are interesting alternative protein source with high nutritional value due to significant content of proteins, vitamins, and minerals [1, 2] and high feed conversion efficiency [3]. In the recent years, crickets, mealy larvae, flies or insect's flours are considered as alternative to meat consumption [4]. While edible insects have food history in Africa, Latin America, and Asia in Europe they still are exotic food sources and belong to so-called "novel foods" [5]. As a food source the insects had little environmental footprint and a higher economic value by cheap protein incorporation. The main problem for part of European consumers is a difficult perception and reluctance to consume the insects as food. A good solution to the problem would be incorporation of edible insects as flours so that they are no longer recognizable [6]. The processing of hybrid meat products made by addition of insect powders has huge potential to introduce these products into consumer's diet. The cricket (*Acheta domestica*) powder contained over 70 % of dry matter, high *p*H and is suitable as additive during the meat processing. Other potential benefits of cricket-based powder are chitin and chitosan which suppress pathogenic microorganisms. Antioxidant activity of the insect powders was reported too [3]. However, the potential risks to the quality of the final meat product exist. The high protein content in cricket powder (up to 60 %) may influence the texture of the product. Another problem is the color deterioration. Cricket powder must be used in an amount that does not impair the sensory characteristics of the product and that would be acceptable to consumers. Therefore, the aim of this work was to explore the influence of the addition of cricket powder on the color, sensory properties and technological characteristics of dry-fermented poultry meat bars.

MATERIALS AND METHODS

Meat raw materials

The chilled to 0 – 4 ºC poultry fillets (m. *Pectoralis Major)* (72 h post mortem, *p*H 6.05), were bought from the local market.

Other ingredients and additives

The cricket powder (Table 1) was provided by "Ento Synergy "LTD, Bulgaria. The CP characteristics (proteins, fats, carbohydrates and energy value) were tested in laboratory Geyacom-Burgas (Protocol 1679-H/14.06.2019). The element composition was measured in the laboratory of the Bulgarian Food Safety Agency (Protocol 163 3/19.08.2019).

The salt was bought from the local market.

Table 1. *Cricket powder characteristics*

Proteins [% DM]*	58.10	Zinc [mg·kg^{-1}]	160.00
Fats [% DM]*	14.43	Manganese [mg·kg^{-1}]	36.00
Carbohydrates [% DM]*	12.90	Iron [mg·kg^{-1}]	60.00
Moisture [%]*	15.47	Calcium [mg·kg^{-1}]	650.00
Energy value [kcal/100 g]	436.03	Sodium [% DM]*	0.43
*p*H	6.83	Magnesium [% DM]*	0.53
Copper [mg·kg^{-1}]	18.50	Phosphorus [% DM]*	0.84

*The protein, fat, carbohydrate, sodium, magnesium and phosphorus contents were calculated as % from the dry matter (DM) according to the data specified by the manufacturer

Sample preparation

The refrigerated (0 – 4 °C) poultry fillets were cut on pieces to approximately 50 g and mixed with 1.5 % salt on cutter machine (EMS Muller, MTK30, Saarbrucken west-Germany). The prepared filling mass was separated of three equal portions.
The samples analyzed in this study will be abbreviated as follows: CR – raw poultry bars without addition of cricket powder (control); 2R – raw poultry bars with 2 % addition of cricket powder; 4R – raw poultry bars with 4 % addition of cricket powder; CD – dry-fermented poultry bars without addition of cricket powder (control); 2D – dry-fermented poultry bars with 2 % addition of cricket powder; 4D – dry-fermented poultry bars with 4 % addition of cricket powder.
In 2R / 2D and 4R / 4D, the pre-weighed 2 and 4 % of CP was added in cutter (Table 2).

Table 2. *Formulation of different samples*

Ingredients	**Samples**		
	CR	**2R**	**4R**
Poultry fillets [g]	1000	1000	1000
Cricket powder [g]	-	20	40
Sodium chloride [g]	15	15	15

The control filling mass (CR and respectively CD after drying) meat bars contained only poultry. Meat bars were formed and then put in the drier (temperature 10 – 12 °C, humidity 90 – 85 %). The dried poultry bars were evaluated after 6 days of drying ($a_W \approx 0.85$).

Sensory analysis

A five member's panel group with proven tasting abilities was used [7]. The samples were scored using 1 to 5 scales. The panelists were passed the triangular test for differentiation of flavor, taste, and color.

Color properties establishment

The CIE L*, a*, b* color properties were determinate by Colorimeter Konica Minolta model CR-410 (Konica Minolta Holding, Inc., Ewing, New Jersey, USA). Before measurements, the colorimeter was calibrated. The total color change between each test sample and the control was calculated, using Equation 1 [8]:

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

where *ΔL*, Δa*, and Δb** are the derivatives of corresponding parameters, respectively.

*p*H determination

*p*H of the poultry bars was determined by *p*H-meter MS 2004 (Microsyst, Plovdiv, Bulgaria), equipped by *p*H combination recorder S 450 CD (Sensorex *p*H Electrode Station, Garden Grove, CA, USA) [9].

Texture profile analysis (TPA)

The analysis is conducted using OB - 05 penetrometer (Labor, Hungary) by the method described by Bourne [10], with certain modifications [11]. The raw samples were measured at 0 + 4 °C. The dry-fermented bars were left for 20 min at room temperature before the analysis. Nine replicates for each film formulation were tested using the following parameters. The meat samples were homogenized and placed in a metal form with dimensions 20/20/30 mm. Structural strength was measured using rounded nozzle attached to the penetrometer holder by compressing for 5 s. The measure of the depth is reported on the scale, and the calculation is performed according to the Equation 2:

$$SS = \frac{K \times F}{h^2} \quad (2)$$

where: *SS* - structural strength, g·cm^{-2}; *K* - constant of the nozzle (k = 1.853); *F* - mass of the nozzle holder system, g (107.8); *h* - measured depth, cm.

Plastic strength determination is made as for the structural strength indicator, using sharp nozzle. The calculation was done according to the following (Equation 3):

$$PS = \frac{K \times F}{h^2} \quad (3)$$

where: *PS* - plastic strength, g·cm^{-2}; *K* - constant of the nozzle (k = 1,853); *p* - mass of the system, g (103.8); *h* - measured depth, cm.

Yield

Calculations for the yield after drying [12] were as follows:

$$Yield\ (\%) = \frac{weight\ after\ drying}{raw\ weight} \times 100 \quad (4)$$

Moisture content

The moisture content determination was based on drying the sample at 104 - 105 °C to a constant weight by hygrometer (AOAC, 1990) [13].

Water activity (a_w)

The water activity of the samples was determined by Novasina AG CH-8853 a_w meter (Zurich, Switzerland) at 20 °C [14].

Statistical analysis

The data of different samples were analyzed independently by SAS software [15]. Differences among means were compared by Student-Newman-Keuls multiple range test. Results were expressed by mean values and standard error. Significance of differences was defined at $p < 0.05$.

RESULTS AND DISCUSSION

Color characteristics

It was established that the use of 2 % cricket powder (CP) reduces the color lightness (L*) in the filling mass by 10 % ($p > 0.05$). Darker color was found after 4 % CP addition (16 % lower than CR). In comparison to reference (CR), CP significantly influence the a* component, which defines color redness (Table 3).

Table 3. *Color characteristics (L*, a*, b*) of raw and dry-fermented poultry bars with addition of cricket powder (CP)*

Sample	CR	2R	4R	CD	2D	4D
L*	$54.34^c \pm 0.12$	$49.42^b \pm 0.15$	$46.47^a \pm 0.14$	$52.91^c \pm 0.21$	$52.12^b \pm 0.18$	$49.75^a \pm 0.17$
a*	$16.51^c \pm 0.17$	$8.96^b \pm 0.11$	$7.16^a \pm 0.07$	$13.88^c \pm 0.21$	$7.63^b \pm 0.05$	$6.99^a \pm 0.07$
b*	$14.50^c \pm 0.15$	$10.11^b \pm 0.13$	$8.19^a \pm 0.10$	$16.30^c \pm 0.20$	$13.34^b \pm 0.16$	$13.02^a \pm 0.15$
ΔE	-	10.03	13.76	-	6.96	8.26

Results are presented as Means ± Standard error of the means (SEM).
^{a,b,c} Means with different superscripts in each row differ significantly ($p < 0.05$) separately for raw (CR, 2R, 4R) and dry fermented meat bars (CD, 2D, 4D).

CP addition decreased 1.85 times and 2.3 times a* value in 2R and 4R filling mass. Similar was the trend in b* component, with 1.43 and 1.77 times decrease in 2R and 4R filling mass, respectively. The dark color of the CP leaded to overall darker filling mass which was observed by the naked eye (Figure 1). However, after drying slight L* deviations between the control (CD) and the cricket enriched bars (2D and 4D) were found.

In the final CP poultry bars, the L* values were 1.5 (2D) and 6.4 % (4D) lower than the control (CD). During the drying the L* component is reduced in control, too. Darker color in pork pâté containing cricket powder was reported [1]. In dry-fermented meat bars with CP addition (2D and 4D) the a* and b* components remain significantly lower than control (CD). The color of food products is one of the key parameters by which consumers choose the product. On the one hand, consumers prefer poultry to be light in color, and the dark colored final products had potential negative effect [16]. According to Tkacz *et al*. [8], ΔE value above 3.5 can be reported as difference between two explored objects. The data observed for ΔE, namely ΔE_{2R} = 10.03, ΔE_{4R} = 13.76, ΔE_{2D} = 6.96, ΔE_{4D} = 8.26, prove that CP addition changed meat color, and this deviation correlate with CP concentration.

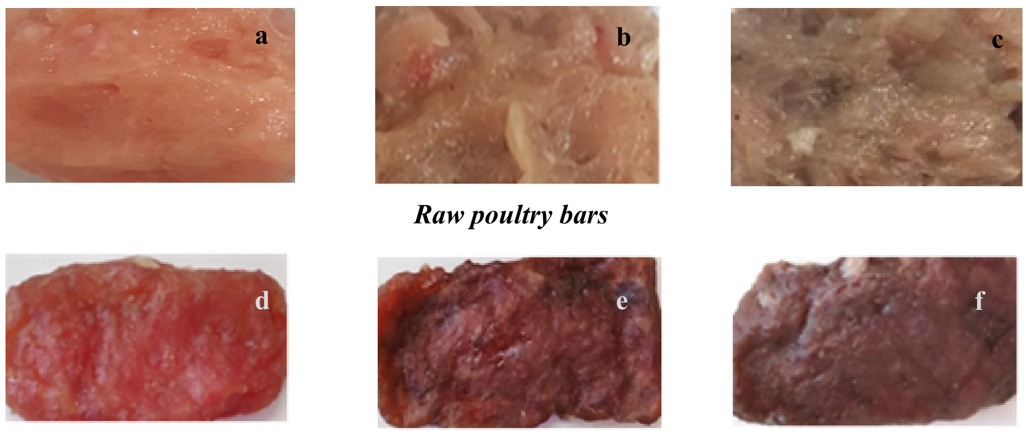

Figure 1. *Photographs of raw and dry-fermented poultry bars with addition of cricket powder: CR (a), 2R (b), 4R (c), CD (c), 2D (e), 4D (f)*

Sensory characteristics

The sensory characteristics were directly affected by the addition of CP in the formulation of the raw filling mass and later in the dry-fermented poultry bars.
The sensory panel awarded the highest scores for overall view, color, consistence and flavor to control CD (Table 4).

Table 4. *Sensory properties of raw and dry-fermented poultry CP enriched bars*

Sample	CR	2R	4R	CD	2D	4D
Overall view	5.0^{c} ± 0.10	4.5^{b} ± 0.10	4.0^{a} ± 0.10	5.0^{b} ± 0.07	4.8^{b} ± 0.15	4.0^{a} ± 0.10
Color	5.0^{c} ± 0.07	4.5^{b} ± 0.13	4.0^{a} ± 0.10	5.0^{b} ± 0.07	4.9^{b} ± 0.10	4.0^{a} ± 0.15
Consistence	5.0^{b} ± 0.07	4.9^{b} ± 0.10	4.6^{a} ± 0.10	5.0^{b} ± 0.10	4.8^{b} ± 0.10	4.5^{a} ± 0.10
Taste	-	-	-	5.0^{b} ± 0.10	4.8^{b} ± 0.10	4.4^{a} ± 0.13
Flavor	5.0^{a} ± 0.07	5.0^{a} ± 0.07	4.9^{a} ± 0.13	5.0^{a} ± 0.10	4.9^{a} ± 0.10	4.8^{a} ± 0.10

Results are presented as Means ± Standard error of the means (SEM)
a, b, c Means with different superscripts in each row differ significantly ($p < 0.05$) separately for raw (CR, 2R, 4R) and dry fermented meat bars (CD, 2D, 4D).

The CP additive decreased L* and a*, which resulted in lower scores for overall view and color in filling mass with CP addition. The dose dependent darkening of the color

was previously reported in pork pâté and durum wheat pasta enriched with cricket powder
[1, 4].
The consumer's the assessment is highly dependent on product appearance, taste and flavor [1]. The use of 2 % CP had slight effect on consistence in raw and dry-fermented poultry bars ($p > 0.05$), but after 4 % CP the consistence of raw mass was very dense and dry bars had rough texture.
The flavor and the taste of 2 % CP enriched meat bars were not differing significantly. Higher CP addition influenced negatively taste of the final product. The use of 4 % cricket protein impairs sensory properties in dry-fermented poultry products. Contrary to our results, Smarzyński *et al.* [1] found that addition of CP in higher concentrations is suitable for improving the texture in enriched pâté.

Physicochemical characteristics and texture profile

No significant difference in *p*H between 2 % enriched bars (2R and 2D) and controls (CR and CD) were observed. With the increase of the amount of CP, the *p*H in raw (4R) and in dry-fermented meat bars (4D) rise ($p < 0.05$). Similar to our results, Kim *et al.* [3] report that CP replacement over 5 % affects the *p*H in final product.
The cricket powder addition decreased a_w in the 2R and 4R samples. This expected decrease is due to high dry matter content in CP ingredient (dry matter 85.83 %, moisture 14.47 %). The different trend in a_w values after drying was observed (Table 5).

Table 5. *pH, a_w, moisture and texture analysis of raw and dry-fermented poultry CP enriched bars*

Sample	CR	2R	4R	CD	2D	4D
*p*H	6.11^{a} ± 0.03	6.15^{a} ± 0.03	6.19^{b} ± 0.01	6.09^{a} ± 0.01	6.11^{a,b} ± 0.03	6.16^{b} ± 0.02
a_w	0.96^{c} ± 0.04	0.95^{b} ± 0.02	0.94^{a} ± 0.02	0.850^{a} ± 0.04	0.870^{b} ± 0.03	0.872^{b} ± 0.01
Moisture [%]	-	-	-	8.01^{b} ± 0.12	8.81^{a} ± 0.25	8.88^{a} ± 0.27
Plastic strength [$g \cdot cm^{-2}$]	0.81^{a} ± 0.05	1.32^{b} ± 0.12	1.53^{b} ± 0.13	2450.00^{a} ± 7.02	3606.00^{b} ± 13.74	3918.00^{c} ± 11.83
Structural strength [$g \cdot cm^{-2}$]	3.60^{a} ± 0.17	7.58^{b} ± 0.31	9.01^{c} ± 0.35	7583.00^{a} ± 14.26	12577.00^{b} ± 18.95	23720.00^{c} ± 21.85
Yield [%]	-	-	-	58.65^{a} ± 0.90	60.90^{b} ± 1.20	64.39^{c} ± 1.00

Results are presented as Means ± Standard error of the means (SEM).
$^{a, b, c}$ Means with different superscripts in each row differ significantly ($p < 0.05$) separately for raw (CR, 2R, 4R) and dry fermented meat bars (CD, 2D, 4D).

Compared to control (CD), a_w was 2.3 % higher ($p < 0.05$) and the moisture content increased by 11 % ($p < 0.05$) in CP enriched meat bars (2D and 4D). One possible reason is the more significant moisture retention in CP bars compared to controls. According to our results, the higher *p*H in CP ingredient resulting in higher *p*H in dry-fermented CP enriched bars (2D and 4D) and increase the water holding capacity of CP meat bars. The yield in 2D and 4D significantly increased by 4 % and 10 %

approximately. Despite the additional cost of CP, the price of the product will not change significantly due to the higher yield. At the same time, CP hybrid meat products will have a higher protein content (flour contains about 60 % protein) and better mineral composition.

The addition of such dry substance as CP severely affected on plastic strength (PS) and structural strength (SS) of meat bars before and after drying process. Similar results were reported by Smarzyński *et al*. [1] and Kim *et al*. [3]. The increment in CP and PS values show good correlation with concentration of CP. The data for moisture, PS and SS confirmed results from sensory analysis for consistence of the filling mass and the texture of meat bars. The consistence of raw 4R poultry bars was dense and the texture of 4D final product was too dry and firm (Table 4 and Table 5).

CONCLUSSION

The color characteristics of dry-fermented poultry bars were significantly influenced by CP addition. The color lightness and redness decreased in dose depended on manner. The strong correlation between sensory properties, color parameters and concentration of CP exists. In accordance with sensory characteristics - overall view, color, consistence, CP can be successfully used up to 2 % in CP dry-fermented poultry products.

CP addition up to 4 % had negative effect on the color, sensory properties, structural and plastic strength on the filling mass in studied meat bars.

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