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COMBATING FOOD WASTE BY MAKING A FUNCTIONAL PRODUCT FROM A SLAUGHTERHOUSE BY-PRODUCT AND PROFILING ITS NUTRITIONAL VALUE

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Abstract

The main objective of the current study was to use a by-product from the deboning process of poultry meat and use it to produce products with high nutritional value. Four product assortments (chicken and turkey soup concentrate and chicken and turkey stock respectively) were produced using bone tissue of the two species as biological material. It was found that there were no significant differences in the technological process to obtain them, the most varied differences being evident in the raw chemical composition, where chicken broth concentrate had the highest percentages of water (69.5%), protein (20.1%) and collagen (18.2%) compared to chicken stock where a higher rate of fat (17.6%) was evident. In the case of turkey backbone products, the highest percentage of fat was found in the concentrated broth, with the stock having the highest percentages of water (65.2%), protein (18.8%), and collagen (17%). The color characteristics are closely related to the Maillard reaction resulting from the cooking operation of the biological material, resulting in products with a positive sensory appearance and microbiological safety.

Key words: *bone stock, circular economy, concentrated soup, food waste.*

INTRODUCTION

Food waste is a major concern for global food security because it has a significant economic, environmental, and social impact. The circular economy is a key solution to the problem of secondary flows, as it promotes the reuse of resources and minimization of waste. The circular economy is a system aimed at stabilizing economic growth through improved management and more efficient use of by-products while minimizing waste. In particular, the concept of 'end-of-life' is replaced by the reuse of waste from industrial production to create additional value. In this context, "industrial symbiosis" seems to be the best way to achieve a circular economy. One of the main problems is related to the lack of a homogeneous and standardized separate collection of biowaste at the national level, which makes the recovery of bones, skin, and food waste from the processing of chicken carcasses a difficult objective (Bux & Amicarelli, 2022).

Globally, meat consumption is on the rise due to population and income growth. The vertically integrated poultry meat rearing and slaughtering sector is the most used sector from processing to consumption, (Ciobanu et. al., 2019a). According to the National Institute of Statistics (INS), poultry meat production in Romania increased in 2023 by 5.5% compared to 2022, totaling 539,867 tons. In January 2024, 28.383 million birds were slaughtered, a significant increase compared to January 2023 with a total of 26.880 tons heads and compared to December 2023 when 24.963 million heads of poultry were slaughtered.

The meat supply chain generates waste and food losses at different stages. However, a considerable amount is produced during the slaughtering stage where the animal is transformed into edible and inedible parts, resulting in numerous animal offal (Karwowska et al., 2021; Ciobanu et al., 2019b). Slaughterhouses are a major contributor to the overall problem of food losses, and with population growth, industrialization, and urbanization, the management of animal by-products from these facilities becomes a huge challenge.

The OECD-FAO Agricultural Outlook projects an increase in global meat production, with pork leading the way as the second-largest meat category after poultry (OECD/FAO, 2021).

According to Song et al. (2016), after deboning and packing meat for retail sale, based on carcass weight, about 6-12% of bones remain. These bones are considered to be notable products to be transformed into high-value-added products by applying effective strategies to ensure sustainability (Toldora et al., 2021). Thus, one of the most effective strategies to valorize bones is the production of bone concentrates and bone stock. Concentrated bone broth is popular due to its rich nutrients and unique flavors (Meng et al., 2022).

MATERIALS AND METHODS

The stages of the present work were carried out at the Iasi University of Life Sciences (IULS) in Iasi, within the Department of Food Technologies, with the actual research activity being carried out in the Meat Processing Workshop, the Meat and Meat Products Technology Laboratory, and the Microbiology Laboratory. The biological material for analysis was purchased from different processing plants in Romania and consisted of poultry backbones from two different species *Gallus gallus domesticus* and *Meleagris gallopavo domesticus*. The main objective of the research was to obtain four functional products (chicken soup concentrate and turkey stock) from the two species, following characteristics related to the technological flow, nutritional, color, and microbiological characteristics of the products obtained. The technological flow applied included the stages of cooking, pressure cooking, the addition of vegetable mass (in the case of stock products), filtering, dosing, and sterilization of the product obtained. The heat treatment parameters applied are described in Table 1.

Table 1. Heat treatment parameters applied

Parameter	Temperature (ºC)	Time (hours)
Baking	140^0C	1
Boiling	110^0C	12

To observe the extraction capacity of organic compounds from the bone structure of the two bird species, the raw chemical composition was determined by monitoring the percentage of protein, collagen, and other indices such as moisture and fat. Chemical composition was determined by applying a versatile near-infrared (NIR) spectrophotometric method using the Food Check meat analyzer. A digital pH-meter for high-viscosity products (testo 206-pH2) was used to determine the pH of the four products obtained. The color characteristics were analyzed applying the CIEL*a*b* system using the Konica Minolta Chroma Meter CR-410 color analyzer, measuring the parameters of lightness (L*), red-green (a*), and yellow-blue (b*) color (Ciobanu et al., 2013). The calculation of losses incurred during the technological flow of obtaining was calculated according to the formula presented by Boișteanu et al. (2023).

$$\text{Cooking loss (\%)} = \frac{weight\ of\ raw\ sample - weight\ of\ cooked\ sample}{weight\ of\ raw\ sample} \times 100$$

The microbiological determinations applied to the four products consisted of determining the total aerobic bacterial count (TAPC), the microbial load of *Staphylococcus aureus*, *Escherichia coli,* and the presence or absence of *Salmonella*. Rapid culture media were used, with dilutions up to 10-3 with a 24-hour incubation period.

RESULTS AND DISCUSSIONS

Table 2 reports the losses incurred during the heat treatment steps applied to produce the four samples. It can be seen that in the cooking stage, the percentage losses were higher in the chicken concentrate with a percentage of 25%, and in the boiling stage, the highest percentages were found in the turkey concentrate (90.14%) and also in the turkey stock (56.6%).

The distribution of the numerical raw chemical composition data was determined using IBM SPPS software by applying an independent sample t-test to determine if there were significant differences between the means of the measured variables for the two independent groups (concentrate and stock), the test being applied to the generated results of the samples from the two species *Gallus gallus domesticus* and *Meleagris gallopavo domesticus*. (Table 3)

Table 2. Heat treatment losses

Parameter	CC	SC	TC	TS
Initial weight of biological material (kg)	13.1	5.75	13.9	5.3
cooking losses (%)	25	-	18	-
Vegetable meal additive (kg)	-	10	-	10
Water added (L)	60		72	
Boiling losses (%)	84.9	43.86	90.14	56.6

CC - Chicken concentrate; SC - Chicken stock; TC - Turkey concentrate; TS - Turkey stock.

Table 3. Descriptive Statistics for *Gallus Gallus domesticus*

	Product	N	Mean	Std. Deviation	Std. Error Mean
Fat %	CC	5	9.700	0.0707	0.0316
	SC	5	17.620	0.4919	0.2200
Moisture %	CC	5	69.580	0.0837	0.0374
	SC	5	63.140	0.4506	0.2015
Protein %	CC	5	20.100	0.0000	0.0000
	SC	5	18.300	0.1000	0.0447
Collagen %	CC	5	18.260	0.0548	0.0245
	SC	5	16.420	0.1304	0.0583
S.U %	CC	5	30.420	0.0836	0.0374
	SC	5	36.860	0.4505	0.2014

CC - Chicken concentrate; SC - Chicken stock

Table 3 illustrates that chicken bone products' highest percentages of protein and collagen are found in chicken concentrate, with values of 20.1% for protein and 18.26% for collagen in dry matter. It is also highlighted that the percentages of dry matter of 30.42% in chicken concentrate and 36.86% in chicken stock are inversely proportional to the two indices highlighted, while the percentage of fat is directly proportional.

Table 4. Averages between comparison tests (Levene's Test and Independent Sample Test) for *Gallus gallus domesticus*

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance: One Sided p	Significance: Two Sided p	Mean Diff.	Std. E. Diff.	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper
Fat %	1	24.647	0.001	-35.634	8	<.001	<.001	-7.9200	0.2223	-8.4325	-7.4075
	2			-35.634	4.165	<.001	<.001	-7.9200	0.2223	-8.5276	-7.3124
Moisture	1	12.980	0.007	31.424	8	<.001	<.001	6.4400	0.2049	5.9674	6.9126
	2			31.424	4.276	<.001	<.001	6.4400	0.2049	5.8852	6.9948
Protein	1	16.000	0.004	40.249	8	<.001	<.001	1.8000	0.0447	1.6969	1.9031
	2			40.249	4.000	<.001	<.001	1.8000	0.0447	1.6758	1.9242
Collagen	1	4.356	0.070	29.093	8	<.001	<.001	1.8400	0.0632	1.6942	1.9858
	2			29.093	5.369	<.001	<.001	1.8400	0.0632	1.6807	1.9993
S.U. %	1	12.979	0.006	-31.423	8	<.001	<.001	-6.4399	0.2049	-6.9125	-5.9674
	2			-31.423	4.275	<.001	<.001	-6.4499	0.2049	-6.9948	-5.8851

1 - Equal variances assumed; 2 - Equal variances not assumed.

The Levene test was applied to identify the equality of variances between the two products obtained from *Gallus gallus domesticus*. F-values correlated with p-values indicate significant values for fat, water, and protein indices. In the case of collagen percentage

F-value = 4.356 and p-value = 0.070 noting that the two values are insignificant (Table 4). Regarding the T-test, it can be observed that there are significant values for all the determined indices (p-value being < 0.001).

Table 5. Descriptive Statistics for *Meleagris gallopavo domesticus*

	Product	N	Mean	Std. Deviation	Std. Error Mean
Fat %	TC	5	17.880	0.4764	0.2131
	TS	5	15.040	0.2793	0.1249
Moisture %	TC	5	63.000	0.3674	0.1643
	TS	5	65.260	0.2408	0.1077
Protein %	TC	5	18.180	0.1095	0.0490
	TS	5	18.880	0.0837	0.0374
Collagen %	TC	5	16.220	0.1643	0.0735
	TS	5	17.000	0.1000	0.0447
S.U. %	TC	5	37.000	0.3674	0.1643
	TS	5	34.740	0.2408	0.1077

TC - Turkey concentrate; TS - Turkey stock.

While in chicken bone products the highest values were found in concentrate, in turkey bone products the highest percentages of protein and collagen were found in turkey stock. Thus the value of the percentage of protein about dry matter (34.74%) is 18.88% and the value of collagen is 17%. In this case, too, the percentages of the indices analyzed are inversely proportional to the S.U. %, with only fat being directly proportional (Table 5).

Table 6. Averages between comparison tests (Levene's Test and Independent Sample Test) for *Meleagris gallopavo domesticus*

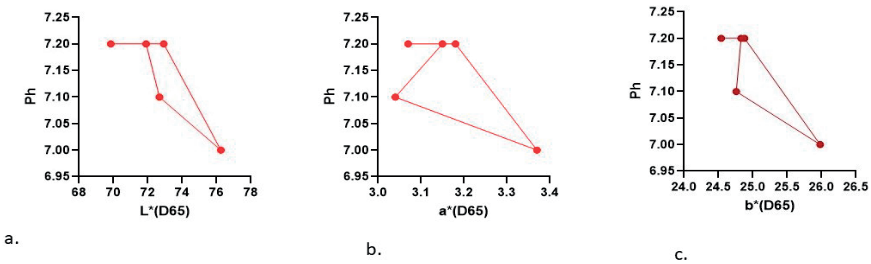
		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One Sided p	Two Sided p	Mean Diff.	Std.Error Diff.	Lower	Upper
Fat %	1	7.910	.023	11.499	8	<.001	<.001	2.8400	.2470	2.2705	3.4095
	2			11.499	6.459	<.001	<.001	2.8400	.2470	2.2459	3.4341
Moisture %	1	5.744	.043	-11.503	8	<.001	<.001	-2.2600	.1965	-2.7131	-1.8069
	2			-11.503	6.901	<.001	<.001	-2.2600	.1965	-2.7259	-1.7941
Protein %	1	2.169	0.179	-11.355	8	<.001	<.001	-7.000	.0616	-.8422	-.5578
	2			-11.355	7.482	<.001	<.001	-7.000	.0616	-.8439	-.5561
Collagen %	1	6.649	.033	-9.067	8	<.001	<.001	-7.800	.0860	-.9784	-.5816
	2			-9.067	6.606	<.001	<.001	-7.800	.0860	-.9859	-.5741
S.U. %	1	5.743	0.04	11.503	8	<.001	<.001	2.260	.1965	1.8069	2.7130
	2			11.503	6.901	<.001	<.001	2.260	.1964	1.7940	2.7259

1 - Equal variances assumed; 2 - Equal variances are not assumed.

For the crude chemical composition of the batches obtained from turkey back, Table 6 shows that the F-values correlated with p-values indicate significant values for the fat, water, and collagen indices, and the F-value = 2.169 correlated with p = 0.179 of the protein index being insignificant. The t-test confirms (p <.001) that all the values of the indices taken in the analysis are significant.

Table 7. Correlation Pearson L*, a*, b* with pH for Chicken Concentrate

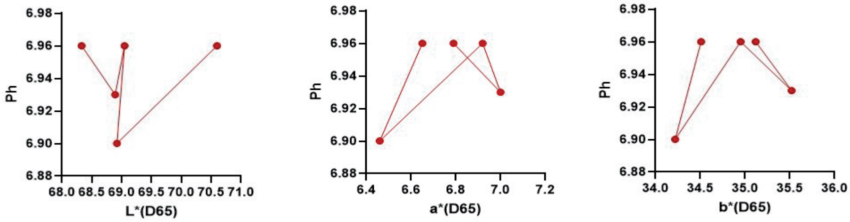
Pearson r	L*	a*	b*
r	-0.8473	-0.6346	-0.8552
95% confidence interval	-0.9897 to 0.1386	-0.9724 to 0.5628	-0.9903 to 0.1102
R squared	0.7179	0.4027	0.7314
P-value			
P (two-tailed)	0.0700	0.2501	0.0647
P-value summary	ns	ns	Ns
Significant? (alpha = 0.05)	No	No	No
Number of XY Pairs	5	5	5



To determine the correlation between color degree and pH index, the Person correlation was applied. For color determinations, 5 readings were taken for each product and one reading was taken for pH determination. From Table 7 it can be seen that the r-value of the brightness, color grade red-green, and yellow-blue show an insignificant correlation for the chicken concentrate sample (L* = -0.8473, a* = -0.6346, b* = -0.8552) (Table 7). It can be observed that concentrated soups (chicken and turkey) have higher brightness (L*) and pH values, while stocks (chicken and turkey) have lower brightness (L*) and pH values. Thus, the addition of vegetables improved the color of the product but led to a decrease in pH value.

Table 8. Correlation Pearson L*, a*, b* with pH for Chicken Stock

Pearson r	**L***	**a***	**b***
r	0.2440	0.4820	0.3459
95% confidence interval	-0.8134 to 0.9268	-0.6964 to 0.9572	-0.7720 to 0.9410
R squared	0.05954	0.2324	0.1196
P-value			
P (two-tailed)	0.6924	0.4109	0.5685
P-value summary	ns	ns	ns
Significant? (alpha = 0.05)	No	No	No
Number of XY Pairs	5	5	5

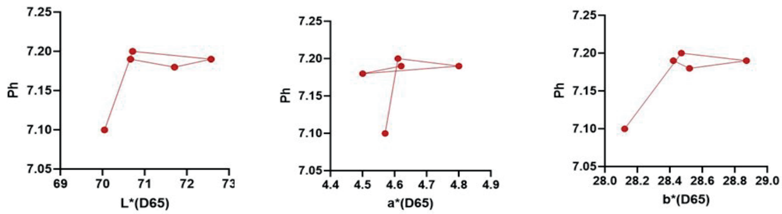


a. b. c.

The chicken stock showed significant correlation values between the two determinations, with R-values being positive for all determinants, as shown in Table 8.

Table 9. Correlation Pearson L*,a*,b* with pH for Turkey Concentrate

Pearson r	L*	a*	b*
r	0.5440	0.3083	0.7286
95% confidence interval	-0.6505 to 0.9637	-0.7884 to 0.9360	-0.4303 to 0.9805
R squared	0.2959	0.09503	0.5308
P value			
P (two-tailed)	0.3432	0.6138	0.1627
P value summary	ns	ns	Ns
Significant? (alpha = 0.05)	No	No	No
Number of XY Pairs	5	5	5

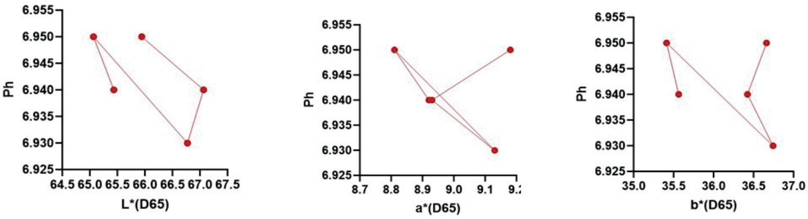


a. b. c.

Concentrated turkey soup also (Table 9) shows significant values for the Person correlation coefficient (r) (L* = 0.5440, a* = 0.3083, b* = 0.7286)

Table 10. Correlation Pearson L*,a*,b* with pH for Turkey Stock

Pearson r	L*	a*	b*
r	-0.6377	-0.2578	-0.3941
95% confidence interval	-0.9727 to 0.5591	-0.9288 to 0.8083	-0.9471 to 0.7484
R squared	0.4067	0.06644	0.1553
P value			
P (two-tailed)	0.2470	0.6755	0.5115
P value summary	ns	ns	Ns
Significant? (alpha = 0.05)	No	No	No
Number of XY Pairs	5	5	5



Also in the turkey stock samples (Table 10), the Person correlation coefficient value (r) indicates insignificant values of the relationship between the color indices and the pH value of the analyzed sample (L= -0.6377, a*= -0.2578, b*= -0.3941).

Table 11. Results of microbiological determinations

Product	Dilution	PCA CFU/mL	*Staphylococcus aureus* CFU/mL	*Escherichia coli* CFU/mL	*Salmonella* (CFU/25mL)
			Logarithm number		
CC	10^{-2}	3.778151	2.30103	0	Negative
CC	10^{-3}	4.414973	3.60206	0	Negative
SC	10^{-2}	3.322219	0	0	Negative
SC	10^{-3}	4.30103	0	0	Negative
TC	10^{-2}	3.612784	0	0	Negative
TC	10^{-3}	3.477121	0	0	Negative
TS	10^{-2}	3.880814	2.477121	0	Negative
TS	10^{-3}	5.113943	3.477121	3.477121	Negative

The values of microbiological results for concentrates and stocks made (Table 11), expressed in logarithmic numbers, did not exceed the limits imposed by Ordin 976 of 29 December 2015, according to Manoliu et al. (2023).

CONCLUSIONS

Turning the bones obtained from the deboning process of poultry meat into a functional product with high nutritional value is based on the process of combating food waste and profiling the circular economy. These products can have a wide use both in the technological field, through their additive in different meat preparations presenting superior nutritional characteristics with a maximum value of 20.1% protein percentage evidenced in concentrated chicken soup and a minimum of 18.1% found in concentrated turkey soup. They can also be used in the HoReCa field as a cooking base thanks to the vegetable addition of 10%, this addition enhances the taste and sensory aspect of the cooked dishes. The sensations caused by different factors produce a complete perceptual experience resulting in the final consumer response (Ciobanu et al., 2023). At the same time, the collagen found in these products can easily replace thickening additives used in the meat processing industry as well as in various soups, sauces, etc., being safe products with low microbiological activity.

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