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The Food for Feed Concept: Redefining the Use of Hotel Food Residues in Broiler Diets

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Abstract: The large quantities of food waste that are generated every year have raised management concerns. Animal diets might be a feasible strategy for utilizing food waste and partially replacing commercially available feedstuffs. The present study examined the potential use of food waste originating from hotels for broiler chickens' diets. Two hundred and forty (240) one-day-old broilers were allocated into four treatment groups, namely, control (C), non-meat treatment (NM), non-sterilized treatment (NS) and sterilized treatment (S), each with 5 replicate pens of 12 broilers. The experimental period lasted 42 days. Several parameters were recorded throughout the experiment, such as the initial and final body weight, the feed conversion ratio (FCR), the traits, some biochemical and hematological parameters, the weight of internal organs and selected breast meat quality indices. The results showed no major differences in health parameters and the carcass quality traits. There was also no difference in growth rate between the three groups (C, NS, S), but broilers fed the NM diet (without meat remnants) had a significantly lower growth rate by 11.4% compared to the control. Food waste residues can be an alternative feedstuff for broiler chickens and can maintain performance at acceptable levels.

Keywords: broilers; carcass yield; food residues; sterilized; growth performance; meat quality; waste

Citation: Giamouri, E.; Pappas, A.C.; Papadomichelakis, G.; Simitzis, P.E.; Manios, T.; Zentek, J.; Lasaridi, K.; Tsiplakou, E.; Zervas, G. The Food for Feed Concept: Redefining the Use of Hotel Food Residues in Broiler Diets. *Sustainability* **2022**, *14*, 3659. https://doi.org/10.3390/su14063659

Academic Editor: Antonio Zuorro

Received: 18 February 2022
Accepted: 17 March 2022
Published: 21 March 2022

1. Introduction

Approximately 17% of the global food production is wasted, with 61% deriving from households, 26% from food services and 13% from the retail sector [1]. According to the United Nations Food and Agriculture Organization, food wastage is a commonly used definition that refers to unconsumed food and includes both food loss and food waste [2]. The European Union generates around 102.5 million tons, the United States about 61 million tons and China 92.4 about million tons of wastage in a year [3]. By the end of 2025, municipal food waste is expected to reach 2.2 billion tons [4]. In developing countries, 30% of the produced food is lost during the post-harvest period, while in developed countries, there is a 40% loss during the retail and consumer phase [3,5].

Food waste is a problem with many socioeconomic and environmental aspects. Water, land, energy and fossil fuels are resources that are used for food production, but they are inefficiently used in the case of unconsumed food. In order to mitigate food waste, it is necessary to take actions; among the possible ways of dealing with this issue is the conversion of food waste into animal feed, which is ranked in the third position according

to the United States Environmental Protection Agency [6]. However, preventing the generation of food waste remains the main goal among countries. The upcycling of food waste as animal feed seems a more sustainable action compared to anaerobic digestion and composting, as far as environmental and health issues are concerned [7].

The generation of food waste releases significant amounts of greenhouse gas emissions. Moreover, commercial diets that are mainly formulated with grains not only produce about half of the greenhouse gas emissions related to animal production because of deforestation but their production also causes a reduction in natural resources [8–10]. Japan and South Korea deploy food waste as animal feed, which is a major technique of their waste management strategy that assures partial independence from commercial animal feed [11]. In the poultry production sector, the cost of nutrition might be reduced with the use of wastes and by-products as a substitute in diets [12].

The transformation of food waste with current processing methods creates safe feed for animals with additional nutritional value [13,14]. Waste that originates from fruit and vegetables has a significant nutritional value but its composition changes slightly over time, remaining close to the annual mean [15]. Similarly, a study by Maietta et al. showed that artichoke waste is rich in polyphenolic compounds [16], thus it can be used in animal diets. On the other hand, food waste that originates from the consumption phase has high moisture content and an undefined composition [17]. As food waste mainly consists of unconsumed food, it is likely to be an important source of proteins, lipids, bioactive compounds and micronutrients. The protein content of food waste might be a solution for the lack of protein reserve [18], while the reuse of vegetables, fruits, cereals and grains for animal diets is strongly encouraged [19]. Moreover, the utilization of fish by-products as active ingredients creates adding value products and promotes an eco-friendly approach in fish production [20].

An important drawback related to food waste is the large variation in the kind and the origin of food waste that puts a barrier on its utilization [21]. Additionally, the percentage of pathogen microorganisms appears to be high in food waste and needs to be eliminated with several processes, such as heating treatment [22,23]. Several disease outbreaks have taken place in previous years that could be linked with incompletely cooked food waste fed to animals. In the United Kingdom in 2001, an outbreak of foot and mouth disease was caused by airline food leftovers [24], while bovine spongiform encephalopathy (BSE) in 1980 was derived from contaminated meat meal in cattle [11]. The recent amendment of the European regulation 2021/1372/EC [25] states that modified animal protein from poultry might be used in pig nutrition and vice versa but not in the diets of the same kinds of animals (recycling within the same animal species).

The present study was part of a LIFE project and focused on the transformation of hotels' food waste into valuable products and their use in animal diets. An environmentally friendly solar drying procedure was used in order to remove moisture from the food waste. For the project, several types of food residues were used for feeding monogastrics, such as residues of plant origin solely and residues containing meat leftovers with or without sterilization. The purpose of this study was to assess the feasibility of different types of hotel food wastes to be incorporated in broiler diets by determining the broiler performance and meat quality.

2. Materials and Methods

2.1. Animals, Diets and Experimental Design

Following collection from hotels in Crete, food waste was sorted manually, grounded, pulverized and introduced in a solar unit for drying. Afterward, microbiological parameters regarding *Escherichia coli*, *Salmonella* spp., *Clostridium perfigens*, *Staphylococcus* spp., *Listeria monocytogenes* and *Listeria* spp. were examined in accordance with the Scientific Opinion of the Panel on Biological Hazards [26], the European Guide of Feed Manufacturers [27] and the 2005/2073/EC European regulation [28]. The compositional analysis for the non-sterilized material was presented in our preliminary study by Giamouri et al. [29]. Re-

garding the composition of the non-meat material, it should be noted that fresh fruits were the main component (46.65%), while fresh vegetables/salads and cooked meals/snacks constituted 14.64% and 26.73%, respectively. Non-sterilized and sterilized materials had initially similar compositions. The sterilized material was processed at 121 °C for 20 min at 1 atm. The amino acid profile was determined, and metabolizable energy was calculated to be 11.34 MJ/kg for the non-meat, 16.03 MJ/kg for the non-sterilized and 15.66 MJ/kg for the sterilized materials. Metabolizable energy was calculated as reported previously [29]. The chemical analysis for the non-meat, the non-sterilized and the sterilized products is presented in Table 1.

Table 1. Determined composition (%) and calculated analysis of the non-meat, non-sterilized and sterilized food waste materials.

	Determined Composition (%)		
	Non-Meat	**Non-Sterilized**	**Sterilized**
Dry matter	90.96	83.93	86.96
Ash	6.17	6.33	6.17
Crude protein	15.24	21.07	20.86
Ether extract	11.88	22.85	21.85
Crude fibre	10.07	3.22	3.4
Starch	26.80	26.8	26.8
Total sugars	3.5	3.5	3.5
	Analyzed Content		
Metabolizable energy [1] (MJ/kg)	11.34	16.04	15.66
Ca (g/kg)	8.6	8.6	8.6
Mg (g/kg)	0.9	0.9	0.9
P (g/kg)	3.2	3.2	3.2
Available P (g/kg) [1]	1.1	1.1	1.1
Na (g/kg)	7.9	7.9	7.9
K (g/kg)	9.2	9.18	9.2
Lys (g/kg)	9.1	8.9	8.5
Meth (g/kg)	2.8	3.7	3.8
Cyst (g/kg)	2.3	2.7	3.1
M + C (g/kg)	5.1	6.5	6.9
Threo (g/kg)	7.3	6.7	7.2
Arg (g/kg)	7.7	7.9	8.0
Iso (g/kg)	8.2	8.4	7.9
Hist (g/kg)	3.9	4.2	3.9
Val (g/kg)	9.5	9.9	1.66
Tyr (g/kg)	5.7	5.0	5.7
Glyc (g/kg)	9.0	9.4	8.3

[1] Calculated analysis results.

Two hundred and forty, one-day-old, male Aviagen Ross 308 broilers were used in the experiment. A commercial hatchery provided the broilers. The experiment lasted 42 days. The Ethical Committee of the Agricultural University of Athens approved the housing and care conditions, while directive 2010/63/EC [30] for the protection of animals used for scientific purposes was followed.

The experimental unit was a pen. Broilers were randomly assigned in four dietary treatments with five replicate pens, namely, control (C), non-meat treatment (NM), non-sterilized treatment (NS) and sterilized treatment (S). In the (C) treatment, broilers were fed a control diet based on corn and soybean meal with no food waste. In the non-meat treatment (NM), broilers were fed a diet with 100 g dehydrated food residues without any meat/kg feed. In the non-sterilized treatment (NS), broilers were fed a diet with 100 g non-sterilized dehydrated food residues/kg feed, and in the (S) treatment, broilers were

fed a diet with 100 g sterilized dehydrated food residues /kg feed. Diets met the National Research Council requirements for poultry [31].

Each replicate pen consisted of 12 broilers (60 birds per treatment). Wheat straw was used as litter in a 2 m^2 capacity pen. The stocking density in the pens complied with Directive 2007/43/EC [32] and did not exceed 33 kg/m^2 at any time. A heating infrared lamp per pen was used to keep the broilers warm. The light and temperature schedule followed the Ross guidelines. Broilers were fed the appropriate diet according to their growth phase. In the first phase, a starter diet was fed for 0–10 days, a grower diet for 11–24 days and a finisher diet for 25–42 days. Feed and water were provided ad libitum to the broilers. The determined and calculated compositions for the starter, grower and finisher diets are presented in Tables 2–4, respectively. Diets were formulated to be isoenergetic and isonitrogenous. One bird/pen (5 birds per treatment) was moved to individual digestibility cages and fed the basal diets with an addition of 3 g TiO_2/kg. Titanium dioxide was ground into the feedstuffs.

Table 2. Determined and calculated analysis results of the components (%) of the starter (0–10 days) diets for the control, non-meat, non-sterilized and sterilized treatments.

	Starter			
Ingredients	**Control**	**Non-Meat**	**Non-Sterilized**	**Sterilized**
Food waste with no meat	-	10	-	-
Sterilized food waste	-	-	-	10
Food waste	-	-	10	-
Maize	48.47	40.13	45.03	44.74
Soybean meal	42.84	40.97	38.48	38.60
Vitamin and mineral premix [1]	0.20	0.20	0.20	0.20
Limestone	1.41	1.20	1.22	1.22
NaCl	0.40	0.20	0.20	0.20
Methionine	0.36	0.37	0.37	0.36
Soybean oil	4.47	5.09	2.55	2.73
Lysine	0.24	0.21	0.29	0.29
Threonine	0.10	0.08	0.12	0.11
Monocalcium phosphate	1.43	1.45	1.44	1.44
Choline	0.08	0.10	0.11	0.11
	Determined Composition (%)			
Dry matter	88.69	88.80	88.92	89.18
Ash	5.88	6.00	5.88	5.63
Crude protein	22.94	22.31	23.41	24.44
Ether extract	5.49	6.88	6.51	7.35
Crude fibre	3.76	4.56	3.28	3.55
	Calculated Analyses			
Metabolizable energy (MJ/kg)	12.55	12.55	12.55	12.55
Sodium (g/kg)	1.6	1.6	1.6	1.6
Ca (g/kg)	9.6	9.6	9.6	9.6
Available P (g/kg)	4.8	4.8	4.8	4.8
Lysine (g/kg)	14.4	14.4	14.4	14.4

Table 2. *Cont.*

	Starter			
Ingredients	**Control**	**Non-Meat**	**Non-Sterilized**	**Sterilized**
	Calculated Analyses			
Methionine + cysteine (g/kg)	10.8	10.8	10.8	10.8
Theonine (g/kg)	9.7	9.7	9.7	9.7

[1] Premix supplied per kg of diet: 13,000 IU vitamin A (retinyl acetate), 3500 IU vitamin D_3 (cholecalciferol), 70 mg vitamin E (DL-α-tocopheryl acetate), 7 mg vitamin K_3, 8.5 mg thiamine, 8 mg riboflavin, 5 mg pyridoxine, 0.020 mg vitamin B_{12}, 50 mg nicotinic acid, 15 mg pantothenic acid, 1.5 mg folic acid, 0.15 mg biotin, 1 mg iodine, 50 mg iron, 75 mg manganese, 15 mg copper, 0.3 mg selenium and 75 mg zinc.

Table 3. Determined and calculated analysis results of the components (%) of the grower (11–24 days) diets for the control, non-meat, non-sterilized and sterilized treatments.

	Grower			
Ingredients	**Control**	**Non-Meat**	**Non-Sterilized**	**Sterilized**
Food waste with no meat	-	10	-	-
Sterilized food waste	-	-	-	10
Food waste	-	-	10	-
Maize	52.09	43.75	48.65	48.36
Soybean meal	38.98	37.12	34.63	34.75
Vitamin and mineral premix [1]	0.20	0.20	0.20	0.20
Limestone	1.28	1.07	1.09	1.09
NaCl	0.40	0.20	0.20	0.20
Methionine	0.31	0.31	0.31	0.31
Soybean oil	5.18	5.81	3.26	3.45
Lysine	0.17	0.14	0.21	0.22
Threonine	0.07	0.05	0.08	0.08
Monocalcium phosphate	1.24	1.26	1.25	1.26
Choline	0.07	0.09	0.10	0.10
	Determined Composition (%)			
Dry matter	89.81	89.87	89.82	89.33
Ash	5.50	5.51	5.44	5.59
Crude protein	21.00	21.16	20.86	20.67
Ether extract	8.36	9.65	8.47	8.21
Crude fibre	3.22	3.79	3.05	3.09
	Calculated Analyses			
Metabolizable energy (MJ/kg)	12.97	12.97	12.97	12.97
Sodium (g/kg)	1.6	1.6	1.6	1.6
Ca (g/kg)	8.7	8.7	8.7	8.7
Available P (g/kg)	4.4	4.4	4.4	4.4
Lysine (g/kg)	12.9	12.9	12.9	12.9
Methionine + cysteine (g/kg)	9.9	9.9	9.9	9.9
Threonine (g/kg)	8.8	8.8	8.8	8.8

[1] Premix supplied per kg of diet: 13,000 IU vitamin A (retinyl acetate), 3500 IU vitamin D_3 (cholecalciferol), 70 mg vitamin E (DL-α-tocopheryl acetate), 7 mg vitamin K_3, 8.5 mg thiamine, 8 mg riboflavin, 5 mg pyridoxine, 0.020 mg vitamin B_{12}, 50 mg nicotinic acid, 15 mg pantothenic acid, 1.5 mg folic acid, 0.15 mg biotin, 1 mg iodine, 50 mg iron, 75 mg manganese, 15 mg copper, 0.3 mg selenium and 75 mg zinc.

Table 4. Determined and calculated analysis results of the components (%) of the finisher (25–42 days) diets for the control, non-meat, non-sterilized and sterilized treatments.

	Finisher			
Ingredients	**Control**	**Non-Meat**	**Non-Sterilized**	**Sterilized**
Food waste with no meat	-	10	-	-
Sterilized food waste	-	-	-	10
Food waste	-	-	10	-
Maize	57.60	49.26	54.17	53.87
Soybean meal	33.39	31.52	29.03	29.15
Vitamin and mineral premix [1]	0.20	0.20	0.20	0.20
Limestone	1.16	0.95	0.97	0.97
NaCl	0.40	0.20	0.20	0.20
Methionine	0.28	0.28	0.28	0.28
Soybean oil	5.61	6.23	3.69	3.87
Lysine	0.18	0.15	0.22	0.22
Threonine	0.04	0.03	0.06	0.05
Monocalcium phosphate	1.06	1.08	1.07	1.07
Choline	0.08	0.10	0.11	0.11
	Determined Composition (%)			
Dry matter	89.60	90.39	90.07	90.95
Ash	5.00	5.08	4.97	5.06
Crude protein	18.89	18.70	19.34	19.15
Ether extract	7.90	8.57	9.52	9.16
Crude fibre	2.53	3.60	2.61	2.27
	Calculated Analyses			
Metabolizable energy (MJ/kg)	13.39	13.39	13.39	13.39
Sodium (g/kg)	1.6	1.6	1.6	1.6
Ca (g/kg)	7.8	7.8	7.8	7.8
Available P (g/kg)	3.9	3.9	3.9	3.9
Lysine (g/kg)	11.6	11.6	11.6	11.6
Methionine + cysteine (g/kg)	9.1	9.1	9.1	9.1
Threonine (g/kg)	7.8	7.8	7.8	7.8

[1] Premix supplied per kg of diet: 13,000 IU vitamin A (retinyl acetate), 3500 IU vitamin D_3 (cholecalciferol), 70 mg vitamin E (DL-α-tocopheryl acetate), 7 mg vitamin K_3, 8.5 mg thiamine, 8 mg riboflavin, 5 mg pyridoxine, 0.020 mg vitamin B_{12}, 50 mg nicotinic acid, 15 mg pantothenic acid, 1.5 mg folic acid, 0.15 mg biotin, 1 mg iodine, 50 mg iron, 75 mg manganese, 15 mg copper, 0.3 mg selenium and 75 mg zinc.

Experimental feeds from the three growth phases were milled through a 1 mm screen. Samples were dried in a convection oven at 100 °C for 24 h and DM was calculated (Method 930.15) [33]. Ash was determined after combusting for 5 h at 550 °C. The ether extract was measured with petrol ether in a Soxhlet apparatus (Soxtec Avanti 2050; Foss Tecator AB, Hoganas, Sweden). An autoanalyzer unit (Kjeltec 2300; Foss Tecator AB, Hoganas, Sweden) was used for the Kjeldahl nitrogen (N) analysis and CP was calculated as N × 6.25 (Method 954.01) [33]. The crude fiber was measured using the filter bag system (ANKOM 220 Fiber Analyzer; ANKOM Technology, New York, USA).

2.2. Determination of Body Weight

Body weight (BW) was recorded on days 1 (onset of trial), 10, 24 and 42 (end of the experimental period). Feed intake was also recorded on days 10, 24 and 42, and the feed conversion ratio (FCR) was calculated by dividing feed intake by body weight gain.

Mortality was calculated as the number of broilers that died during the 42 days of the experiment, expressed as a percentage of the total number of birds.

2.3. Digestibility Procedure

On days 38, 39, 40 and 41, samples of feces were collected in order to evaluate the digestibility of nutrients. Feces were oven-dried and ground through a 1 mm sieve. Titanium dioxide in the feed and fecal samples was analyzed using the method of Myers et al. [34]. Briefly, duplicate 0.5 g feed or dried fecal samples were weighed into 250 mL Kjeldahl tubes. In every tube, a reaction catalyst containing 3.5 g of K_2SO_4 and 0.4 g of $CuSO_4$ and 13 mL of concentrated (98%) H_2SO_4 was added, and samples were digested at 420 °C for 2 h. Tubes were left to cool for 30 min, 10 mL of 30% H_2O_2 was added slowly to the tubes and samples were left again for 30 min in order to cool. Distilled water was used to bring the total liquid weight to 100 g, and then samples were filtered through Whatman No. 541 filter paper to remove any precipitate. The absorbance was measured at 410 nm using a spectrophotometer (Hitachi U3010 Spectrophotometer, Japan). The spectrophotometer was calibrated with working standards, with 0, 2, 4, 6, 8 and 10 mg of TiO_2. The 0 mg standard was used to zero the instrument. For the calculations, the following equations were used:

$$\text{AME} = ((\text{g feed})/(\text{kg DM feces}) - (\text{g marker})/(\text{kg DM feed}))/((\text{g marker})/(\text{kg DM feces})) \quad (1)$$

$$\text{AME} = ((\text{g component feed})/(\text{g marker in feed}) - (\text{g component feces})/(\text{g marker in feces}))/((\text{g component feed})/(\text{g marker in feed})) \quad (2)$$

2.4. Carcass Evaluation

On day 42, 15 broilers from each treatment, 3 per replicate pen, were randomly selected and sacrificed (60 in total) via electro stunning and exsanguination, eviscerated and after a 24 h chilling at 4 °C, the carcasses were weighed in order to estimate the dressing percentage. The breast was excised and weighed to calculate the breast yield and was expressed as a percentage of the broilers' final body weight. For meat quality indices in breast muscle (pH_{24}, color, shear force and cooking loss), the right part of the *Pectoralis major* muscle was used.

2.5. Meat Quality Indices

The right part of the breast was used to determine meat quality indices (pH_{24}, color, shear force and cooking loss). A Sentron 1001 pH System (Roden, The Netherlands) was inserted in the right section of the breast muscle 24 h post-mortem. Buffers of 4.0 and 7.0 were used for the calibration of the pH meter (Merck, Darmstadt, Germany). Color indices of the breast muscles were tested after being left for 30 min at room temperature (each measurement was performed in triplicate). L* (lightness), a* (redness) and b* (yellowness) parameters based on CIE-Lab system [35] were measured with a Miniscan XE (HunterLab, Reston, USA). White and black tiles were used as standards.

At first, meat samples were placed in plastic bags and cooked for 30 min at 85 °C in a laboratory water bath. Afterward, samples were left under running tap water for 15 min, dried and weighed to measure cooking loss (%). The Cason et al. [36] method was used and shear force was measured using the testing machine (Zwick Testing Machine Model Z2.5/TN1S; Zwick GmbH & Co, Ulm, Germany) equipped with a shear blade (Warner-Bratzler G146; Instron, Grove City, PA, USA). Every sample was cut into three strips of 1 cm^2, while muscle fibers and peak force values were measured in N/cm^2.

2.6. Hematological and Biochemical Parameters, Internal Organs

Selected hematological and biochemical parameters were determined in order to gather information about the broilers' health profiles. Total blood samples were collected during the slaughter procedure for hematocrit (%) determination, and serum samples were used in order to assess the asparate aminotransferase (SGOT-AST) (U/L), alanine aminotransferase

(SGPT-ALT) (U/L), blood urea nitrogen (BUN) (mmol/L), γ-glutamyltransferase (γ-GT) (U/L), alkaline phosphatase ALP (U/L), cholesterol (mmol/L), total proteins (g/L) and fractions of albumins (g/L) and globulins (g/L) using an automatic analyst ABX Pentra 400 (Horiba-ABX, Montpellier, France). Heart, spleen, liver, kidney, bursa of Fabricius and gizzard were removed from 20 broilers (n = 5) and weighed (KERN plt, Germany, with d = 0.01 g), and their weight was expressed as a percentage of body weight (g/100 g body weight).

2.7. Statistical Analysis

Data were analyzed using the SPSS statistical package (version 17.0) and are presented as means ± SEM. Prior to analysis, data were tested for normality using Kolmogorov–Smirnov's test. Dependent variables that were not normally distributed were transformed according to a two-step approach that (i) transformed the variable into a percentile rank and (ii) applied an inverse-normal transformation to this rank to form a variable consisting of normally distributed z-scores. Subsequently, normal and transformed data were analyzed using one-way ANOVA with diet as the fixed effect. Post-hoc tests were conducted based on Tukey's criterion. A pen was the experimental unit and statistical significance was set at $p < 0.05$.

3. Results

3.1. Animal Growth Performance

The effects of feeding dried food waste with or without meat content and sterilization on broilers' body weight, feed intake, FCR and mortality are presented in Table 5. The average weight gain (AWG) did not differ between the control (C), non-sterilized and sterilized (S) treatments, but the AWG in the non-meat (NM) treatment was significantly lower ($p < 0.05$) than that of the other treatments. The average feed intake (AFI) during the 42 days of the experimental period did not differ significantly between the treatments. Similarly, for the feed conversion ratio, a higher value was marked in the NM group, which indicated a worse utilization of the diet compared to that of broilers of the control (C) and the (NS) groups ($p < 0.05$). As far as the broilers' dressing percentage and breast meat yield (Table 5) were concerned, they were negatively affected ($p < 0.05$) by the inclusion of food waste only in the NM group when compared to the control. The final BW was significantly lower in the NM treatment compared to the other treatments.

3.2. Digestibility Results

Significant differences were observed between treatments. The digestibility of dry matter (DM) was better for the control (C) treatment as compared with NM and S treatments, while between C and NS, there was no significant difference ($p = 0.012$). Similar results were observed for the digestibility of organic matter ($p < 0.05$). The digestibility of crude fiber for C and NM was exceedingly higher compared to the NS and S treatments ($p < 0.05$). The results are presented in Table 6.

3.3. Meat Quality Indices

Table 7 illustrates treatment effects on broilers' meat quality characteristics. Color traits, especially lightness (L*), redness (a*) and yellowness (b*) were similar among the treatments. The pH 24 h post-mortem (pH_{24}), cooking loss and shear force did not differ between the control and treatments with the different food waste materials.

3.4. Biochemical, Hematological Parameters and Internal Organ Weight

Table 8 presents the results of selected biochemical and hematological parameters and Table 9 shows the weights of several internal organs as a percentage of final body weight. This information might be useful as an indicator of the broilers' health. The consumption of food waste without meat, with meat and/or sterilization seemed to have no negative impact on the animal's health, as indicated by the hematological and biochemical parameters

(Table 8). Moreover, the weight of selected internal organs was not also different between treatments (Table 9).

Table 5. Effect of diet on the average feed intake (AFI), average weight gain (AWG), feed conversion ratio (FCR) and mortality during the whole experimental period in broiler chickens (from day 1 to 42) and on final body weight (BW), dressing percentage (DP), breast meat yield (BY) at day 42 in broiler chickens.

	Diet [1]				SEM [2]	*p*-Value [3]
	C	NM	NS	S		
Initial BW (g)	46.5	46.2	46.4	46.4	0.41	0.853
AFI (g)	4644	4564	4746	4755	109.8	0.289
AWG (g)	3148 [a]	2789 [b]	3108 [a]	3058 [a]	76.2	<0.001
FCR (g feed/g gain)	1.47 [a]	1.64 [c]	1.53 [a,b]	1.56 [b,c]	0.031	<0.001
Mortality [4] (%)	13.3	3.3	1.7	5.0	4.64	0.097
Final BW (g)	3194 [a]	2835 [b]	3154 [a]	3104 [a]	76.2	<0.001
DP (%)	75.95 [a]	74.41 [b]	75.32 [a,b]	76.14 [a]	0.452	<0.001
BY (%)	31.76 [a]	29.93 [b]	32.13 [a]	32.39 [a]	0.743	0.007

n = 5. Different superscripts within the same row denote a significant ($p < 0.05$) difference (Tukey's b post hoc test); [1] C—control diet; NM—diet with 100 g dehydrated food residues without any meat/kg feed; NS—diet with 100 g non-sterilized dehydrated food residues/kg feed; S—diet with 100 g sterilized dehydrated food residues/kg feed. [2] Standard error of means. [3] *p*-value of ANOVA. [4] Kruskal–Wallis non-parametric test was used for mortality (means instead of medians are presented for the readers' convenience).

Table 6. Effect of diet on the digestibility of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE) and crude fiber (CF) at days 38–41 in broiler chickens.

	Diet [1]				SEM [2]	*p*-Value [3]
	C	NM	NS	S		
DM	0.781 [a]	0.712 [b]	0.755 [a,b]	0.720 [b]	0.0201	0.012
OM	0.803 [a]	0.733 [b]	0.778 [a,b]	0.745 [b]	0.0192	0.009
CP	0.732	0.721	0.717	0.670	0.0223	0.057
EE	0.903	0.900	0.901	0.878	0.0089	0.268
CF	0.176 [a]	0.140 [a]	0.040 [b]	0.012 [b]	0.0230	<0.001

n = 5. Different superscripts within the same row denote significant ($p < 0.05$) difference (Tukey's b post hoc test). [1] C—control diet; NM—diet with 100 g dehydrated food residues without any meat/kg feed; NS—diet with 100 g non-sterilized dehydrated food residues/kg feed; S—diet with 100 g sterilized dehydrated food residues /kg feed. [2] Standard error of means. [3] *p*-value of ANOVA.

Table 7. Effect of diet on color traits, pH 24 h post-mortem (pH_{24}), cooking loss (%) and shear force values ($100 \times N/cm^2$) of breast muscle in 42-day-old broilers.

	Diet [1]				SEM [2]	*p*-Value [3]
	C	NM	NS	S		
Color traits [4]						
L*	57.06	56.52	55.49	56.66	1.099	0.535
a*	7.51	6.97	7.33	6.91	0.680	0.789
b*	20.92	19.60	19.57	19.53	0.992	0.434
Physical traits						
pH_{24}	5.96	5.97	5.94	6.06	0.091	0.564
Cooking loss (%)	17.54	15.40	16.95	15.31	2.840	0.818
Shear force (N/cm^2)	12.25	13.54	12.74	12.21	1.439	0.775

n = 5. [1] C—control diet; NM—diet with 100 g dehydrated food residues without any meat/kg feed; NS—diet with 100 g non-sterilized dehydrated food residues/kg feed; S—diet with 100 g sterilized dehydrated food residues/kg feed. [2] Standard error of means. [3] *p*-value of ANOVA. [4] L*—lightness (L* 0—dark meat, L* 100—white meat), a*—redness (high a* value indicates red, low a* value indicates green), b*—yellowness (high b* value indicates a tendency toward yellow, low b* value indicates a tendency toward blue).

Table 8. Effect of diet on blood serum glutamate oxaloacetate transaminase (SGOT-AST), glutamate pyruvate transaminase (SGPT-ALT), urea nitrogen (BUN), γ-glutamyl transferase (γ-GT), alkaline phosphatase (ALP), cholesterol, albumins, total proteins, globulins and hematocrit at day 42 in the broiler chickens.

	Diet [1]				SEM [2]	*p*-Value [3]
	C	NM	NS	S		
SGOT-AST (U/L)	810.8	661.4	962.6	671.0	178.25	0.321
SGPT-ALT (U/L)	11.6	7.4	7.6	7.8	1.93	0.131
BUN mmol/L)	0.89	0.57	0.86	0.64	0.18	0.258
γ-GT (U/L)	22.6	27.0	23.2	27.4	4.81	0.662
ALP (U/L)	1534.6	1569.0	1301.6	1254.2	256.26	0.523
Cholesterol (mmol/L)	3.17	3.45	3.68	3.69	0.31	0.313
Albumins (g/L)	11	12	13	13	1.4	0.654
Total protein (g/L)	23	26	26	28	2.9	0.430
Globulins (g/L)	12	14	14	15	1.8	0.373
Hematocrit (%)	28.4	29.8	30.0	27.8	2.27	0.725

$n = 5$. [1] C—control diet; NM—diet with 100 g dehydrated food residues without any meat/kg feed; NS—diet with 100 g non-sterilized dehydrated food residues/kg feed; S—diet with 100 g sterilized dehydrated food residues/kg feed. [2] Standard error of means. [3] *p*-value of ANOVA.

Table 9. Effect of diet on internal organs weight (expressed as % of body weight) at day 42 in the broiler chickens.

	Diet [1]				SEM [2]	*p*-Value [3]
	C	NM	NS	S		
Heart	0.53	0.59	0.56	0.55	0.052	0.713
Spleen	0.09	0.10	0.08	0.09	0.010	0.353
Liver	1.50	1.72	1.75	1.75	0.104	0.075
Kidney	0.21	0.27	0.26	0.23	0.032	0.273
Bursa	0.13 [a]	0.21 [b,c]	0.20 [c]	0.18 [a,b,c]	0.023	0.021
Gizzard	1.50	1.59	1.36	1.47	0.131	0.412

$n = 5$. Different superscripts within the same row denote significant ($p < 0.05$) difference (Tukey's b post hoc test); [1] C—control diet; NM—diet with 100 g dehydrated food residues without any meat/kg feed; NS—diet with 100 g non-sterilized dehydrated food residues/kg feed; S—diet with 100 g sterilized dehydrated food residues/kg feed. [2] Standard error of means. [3] *p*-value of ANOVA.

4. Discussion

The performance parameters of broilers did not differ between the control and the non-sterilized (NS) and sterilized (S) treatments. The weight gain and feed intake of the broilers in the non-sterilized (NS) and sterilized (S) treatments were similar to those of the control (C) treatment, indicating that leftovers may be used in broiler diets without compromising performance. In contrast, the broilers fed a diet with 10% of no-meat leftovers (NM)—mainly fruits and other materials of plant origin—gained less weight compared to the other treatments, despite the fact that the initial body weights of the broilers were alike and the diets were of similar energy and nitrogen content. As far as feed intake is concerned, there was no significant difference between the C, NM, NS and S treatments, but the high fiber content (10.07%) of the product with no-meat might have affected the digestibility and led to poorer performance, indicating that a lower inclusion level of food waste in NM treatment might be rational. Under this context, the FCR values indicated a similar dietary nutrient utilization of nutrients by the broilers of the C, NS and S treatments when 10% of food waste was added, and the poorer performance for the NM treatment, in line with the findings of Chen et al. [37]. These results were also in accordance with the study of Saki et al. [38], who reported no major differences in broilers' body weight, weight gain and FCR when the inclusion level of kitchen waste was 10% (CP = 12.7% and EE = 10.58%), but the results were different with higher levels of 20% and 30%. Kitchen waste included residues of rice, bread, cereal,

vegetables and meat, and was dried at 50 °C for 20 min. In a previous study, dried food waste containing meat (CP = 23.7% and EE = 20%) was added to broiler diets at 15% and appeared to affect the performance, as indicated by a lower feed intake and body weight compared to the control treatment [29]. This indicates that a 15% addition of food waste might not be reasonable. Biscuit and wafer waste could be used as a partial substitute for corn, as reported by Shahryar et al. [39], revealing that the aforementioned products (CP = 12.6%, EE = 4.05%) did not have an important impact on body weight gain and FCR, but increased feed intake, when broilers were fed assorted levels (8, 16 and 24%). Modifications between studies may attribute to the variability. M. L. Westendorf [40] realized that the variability in nutrient content may limit the use of food waste in animal diets. Appropriate control of the source of food waste that is destined for animal nutrition is required in order to embed it in animal diets [41]. Food waste source [41], consumer' age, eating and provenience habits have an impact on the nutritional composition [42–45].

Dry and organic matter digestibility in the control treatment was significantly increased as compared with the NM and S groups. These lower values noted in broilers fed the S diet might indicate lower nutrient digestibility reflected in numerically lower final body weight values in broilers fed the S diet. In other studies, the lower DM digestibility seemed to be connected with lower feed intake, as Brito et al. [46] observed in groups fed shrimp waste and faced a lower digestibility in DM parallel to lower feed intake. Sani et al. [47] replaced maize levels of 0, 10, 20 and 30% with dried kitchen waste (CP = 2.2%, EE = 5.5%) in broiler diets in the finisher phase. No alterations in DM digestibility were found, contrary to the present study. However, crude protein and ether extract were not affected, neither in the present study nor in the aforementioned study. There was a significant difference in the C and NM treatments as far as crude fiber digestibility was concerned. The higher level of crude fiber in the examined materials and afterward in diets might have been responsible for these findings.

The internal organs' weights had no important differences between treatments, with the exception of the bursa of Fabricius. A strong individual variability between bursa weights is unavoidable, but it is not easy to correlate with differences in ingredients present in the diets fed to the broilers. When using 10% of dried food waste (CP = 20.62%, EE = 9.99%), Cho et al. [48] did not find any changes in weights of heart, liver and gizzard in broilers. Additionally, there were no statistically significant differences between biochemical and hematological parameters. The concentrations were within a normal range that might indicate healthy broilers and a low probability of adverse effects of dietary food waste addition. This is in partial disagreement with another study by Giamouri et al. [29], who observed that cholesterol levels were higher in broilers fed a diet with 15% inclusion of food waste. The latter situation may be related to the higher inclusion level.

The quality of breast muscle from broilers as determined by color traits (L*, a*, b*), pH_{24}, cooking loss and shear force was unaffected by the inclusion of various food waste materials. Kainski et al. [49] came to the result that the concentration of myoglobin is associated with a dark color and is affected by the Fe level; a deterioration in colored meat was not observed in the present study. Ayanwale and Aya [50] observed a lower cooking loss in a treatment group fed 20% cornflakes waste (CP = 6.74%, EE = 3.80%) and 80% maize than the control treatment and another treatment with 100% cornflakes waste. Similar results with some exceptions concerning yellowness b* and shear force were obtained when food waste (CP = 23.7% and EE = 20%) was incorporated at a 15% level in broiler diets [29].

This research confirmed that products of food waste can be nutritious feedstuffs for inclusion in broiler diets, maintaining broiler performance at acceptable levels. Final body weights, feed intake, FCR, mortality, carcass yield, meat quality, biochemical and hematological parameters, as well as some organ weights, were unaffected from the use of food waste with meat. Moreover, sterilization had no negative effect on broiler performance when compared to the no-sterilized material and, as a result, might be used as a method to assure high hygiene levels. On the other hand, no-meat food waste led to lighter broilers and a deterioration in FCR with no negative effects on meat quality. Although food waste

materials from hotels seem to be promising feedstuffs for broiler diets, it needs to be evaluated in depth.

Author Contributions: Conceptualization, E.G., A.C.P. and G.Z.; methodology, G.Z.; software, G.P.; validation, G.Z. and A.C.P..; formal analysis, E.G., P.E.S., J.Z. and K.L.; investigation, E.G.; resources, E.G.; data curation, E.G.; writing—original draft preparation, E.G. and A.C.P.; writing—review and editing, E.G., A.C.P., G.P., P.E.S., T.M., J.Z., K.L., E.T. and G.Z.; visualization, G.Z. and E.T.; supervision, G.Z. and E.T.; project administration, T.M.; funding acquisition, T.M. All authors have read and agreed to the published version of the manuscript.

Funding: Funded by GSRT-Greece matching funds for European Projects 2019—Food for Feed (F4F): An Innovative Process for Transforming Hotels' Food Wastes into Animal Feed.

Institutional Review Board Statement: Ethical Committee of the Agricultural University of Athens approved housing and care conditions.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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