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Meat Quality Traits as Affected by the Dietary Inclusion of Food Waste in Finishing Pigs

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Abstract: An increasing world population along with increasing human needs have raised demand for animal origin products. Moreover, high prices of conventional animal feeds have led to a demand for alternative feedstuff. Food waste can be an alternative feed ingredient. The aim of the present study was to investigate the effect of dietary inclusion of dried hotel residues (DHR) on the growth performance, blood biochemical parameters and meat quality traits in finishing pigs. In each of the 2 trials conducted, 20 castrated male pigs were allotted into 2 treatments. In both trials, control treatment pigs were fed a corn-soybean meal-based diet without hotel residues. In the first trial, a DHR1 treatment contained 100 g DHR1/kg with meat residues (approximately 5%). In the second trial, a DHR2 treatment, contained 80 g DHR2/kg with no meat residues. Average daily feed intake tended to be lower and average daily weight gain was lower in DHR1 compared to control pigs in the first trial, while in the second no differences were detected. However, final body weight, FCR and dressing percentage were not affected in any of the two trials. Minor differences in several meat physical traits, hematological parameters were observed among treatments and trials. In conclusion, the results indicate that the dietary addition of DHR did not affect the feed utilization and the quality of the produced meat; hence, the use of DHR in pig feeding can be supported.

Keywords: food waste; pigs; growth performance; lipid oxidation; meat quality

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1. Introduction

The global population will increase from 7.8 billion in 2020 to 10.9 until the end of the century, according to the United Nations Population Division [1]. Nutritional demands are expected to increase in order to cover human needs, while urbanization will alter dietary behavior of people following the growing human population. As a result, more animal origin products are expected to be required, which will cause a pressure in the food market [2]. On the other hand, limited natural resources are likely to put an obstacle in food production [3].

Prices of the main components in monogastric diets are gradually increasing. Corn and soybean have a high nutritional value and constitute the base of monogastric diets.

They are desirable feeds for the pig sector and are broadly used in order to meet market demands, but due to the growth of the population, prices are gone up in recent years [4].

Moreover, in countries where corn is a basic part of both human and animal diets, demand is likely to increase [5].

Globally, about 32% of the food produced gets lost or wasted [6] annually, which is enough to cover more than four times the needs of 800 million people who live under hunger [7]. Gustavsson et al. had estimated a loss or waste of around 1.3 billion tons of food which were destined for human consumption [8]. Food waste is generated at every level of the food supply chain. The definition of food waste refers to the final stages of food supply chain, in retail and consumption level [8–10], while food loss is derived from early stages, in particular production, post-harvest and processing stages [8–10]. In the consumption level, food waste occurs in a large scale from households, supermarkets, restaurants, and hotels. In the European Union, 70% of the total food waste comes from consumption stage [11].

Although there are several methods of handling food waste, some environmental concerns have emerged. Anaerobic digestion, disposing in landfills, and composting are some methods widely used. In addition, alternative options should be used for recycling food waste in valuable products. Food losses and waste that can no longer be used as human food may be recycled and get back in the food chain as animal feeds [12]. In particular, a potential pig feedstuff could result from food waste. It creates economic, environmental, and public goods, as well as it reduces the due cost for animal production [13]. The sustainability of a pork production system depends on the ingredients used for diets and their environmental effects. The environmental footprint of pig system could be minimized by developing environmentally sustainable diets.

The practice of feeding food waste in pigs is not a novel procedure since it is used for years in many countries, as Rochella et al. [14] highlighted. Swine domestication plays a decisive role as food waste generation was common years ago [15,16]. High moisture content of food waste [13], nutrient variability [17] and pathogenic content impose limitations. The source of food waste [13], the year period [18], and other factors such as dietary, ethnic habits and age are factors that determine the composition [19–22]. At the same time, transmission of diseases may occur after the feeding of improperly treated food waste to animals. The outbreaks of several diseases such as African swine fever (ASF) in 1986 [23] and foot and mouth disease (FMD) in 2001 [24], imposed a ban in the utilization of food waste across EU [25] 2002. Since then, the legislation has changed and encourages a more circular food system in the EU. Therefore, properly handled and heated procedures could ensure a microbial safe feed for animal diets [26].

In the present study food waste was gathered mainly from hotels and fed to finishing pig. An innovative and simple processing method with low gas emissions was used, assuring that food waste originated from different sources (mainly from hotels and generally from the hospitality industry or restaurants) are safely transformed. A pioneering drying method using solar energy was used for the dehydration of food waste. The food waste used for the first trial contained meat residues while for the second trial food waste did not contain any meat residues. At the end of the experimental periods, performance and biochemical parameters were measured. Meat quality traits were evaluated in order to detect potential effects from the food waste inclusion. The research was part of a LIFE project for the transformation of hotel food waste in pig and poultry diets.

2. Materials and Methods

2.1. Collect and Analyze Food Waste

In Crete, a trained staff from hotels used plastic bags to place the leftovers/food before put them in the specific bins. During the procedures all food waste was refrigerated. After the collection, food waste was transported to the experimental unit, via refrigerated trucks. In a pre-treatment unit, food waste was hand-sorted and at some point any meat residues were excised; afterwards it was grounded and pulverized. The pulp produced, was driven

by a high-powered pump in the solar drying unit. In an innovative and environment friendly procedure, food waste was pasteurized and solar dried. Solar power was used (directly and indirectly) to treat food waste. A heat pump and a subfloor heating system keep the drying temperature at 55 °C.

A number of analyses were carried out to provide characteristics about the initial material and the quality of the final dried product. The chemical analysis of such products is presented in Table 1. A compositional analysis that was carried out shortly after the solar drying method revealed the principal food waste categories. In particular, the composition of the initial product, before and after the detraction of meat content, presented in Table 2. Moreover, in accordance to the Scientific Opinion of the Panel on Biological Hazards [27], to the European Guide of Feed Manufacturers [28] and to the 2005/2073/EC European regulation [29] the microbiological analyses that carried out in food waste did not show any pathogens, such as *Escherichia coli, Salmonella* spp., *Clostridium perfringens*, *Staphylococcus* spp., *Listeria* spp. and *L. monocytogenes.*

Table 1. Chemical composition of the dried hotel residues used in the first trial (DHR1) and the dried hotel residues with no meat used in the second trial (DHR2).

	DHR1	DHR2
	%	
Dry matter	92.74	85.63
Ash	6.27	12.14
Crude protein	23.76	17.59
Ether extract	20.00	14.75
Crude fibre	6.26	8.62
Digestible energy, MJ [1]	16.62	12.78

[1] Calculated values using the chemical composition of the dried hotel residues.

Table 2. Composition of the dried hotel residues used in the first trial (DHR1) and the dried hotel residues with no meat used in the second trial (DHR2).

Component Category	DHR1	DHR2
	%	
Fresh vegetables and salads	13.92	14.64
Bread and bakery products	5.70	6.00
Fresh fruit	44.37	46.65
Meat and fish	4.90	0.00
Cooked meals and snacks	25.42	26.73
Dairy products and eggs	0.79	0.83
Condiments, sauces, herbs and spices	0.34	0.36
Desserts	0.22	0.23
Confectionery and snacks	0.09	0.09
Processed fruits	0.03	0.03
Other	3.48	3.67
Impurities	0.74	0.77

2.2. Animals, Diets and Experimental Design

Two feeding trials were conducted and pig was the experimental unit. In both trials pigs were obtained from a commercial pig farm. The transportation, the housing conditions and care of pigs conformed to the guidelines of the Ethical Committee of the Agricultural University of Athens and complied with the directive 2010/63/EC [30] on the protection of animals used for scientific purposes.

In the first feeding trial (FT1), a total of twenty (20) 106 day-old castrated male pigs [(Large White × Landrace) × Duroc] were used. The duration of the experiment was 46 days. There were two (2) dietary treatments balanced for body weight (BW) (50.3 ± 2.54 kg; mean ± s.d.), namely control (C1) and DHR1. There were ten pigs per treatment. In C1 treatment, pigs were fed a corn-soybean meal-based diet with no dried hotel residues added. In DHR1 treatment, food waste was added to the diet at a level of 10% in order to avoid any increasing in the ether extract level of the diets. At the same time,

the inclusion level was chosen taking into account the market price of food waste, as an effort to maintain feed cost low.

In the second feeding trial (FT2), twenty (20) 113 day-old castrated male pigs [(Large White × Landrace) × Duroc] were used. The duration of the experiment was 56 days. There were two dietary treatments balanced for BW (52 ± 2 kg; mean ± s.d.) namely control (C2) and DHR2. There were ten pigs per treatment. In C2 treatment, pigs were fed a corn-soybean meal-based diet with no food waste added. In DHR2 treatment, food waste product with no meat residues was added to the diet at a level of 8%.

Feed and water were provided *ad libitum* in pigs of both trials. The experimental diets in each feeding trial were isonitrogenous and isocaloric and were formulated to meet or exceed the NRC (2012) [31] recommendations for finishing pigs (Table 3).

Table 3. Ingredients and chemical composition (g/kg as fed of the experimental diets used in the first (FT1) and the second feeding trial (FT2).

	FT1		FT2	
	C1	**DHR1** [1]	**C2**	**DHR2** [2]
Ingredients				
Dehydrated hotel residues (DHR)	-	100.0	-	80.0
Maize	647.0	629.0	640.0	630.0
Soybean meal, 45%	177.0	130.0	171.0	160.0
Wheat bran	136.0	120.0	130.0	80.0
Vegetable Oil	18.0	0.0	34.5	26.5
Premix [3]	20.0	20.0	20.0	20.0
Calcium carbonate	2.0	-	1.50	-
DL-Methionine, 99%	-	0.2	-	0.5
L-Lysine HCl, 80%	-	0.8	2.0	2.0
L-Threonine, 99%	-	-	1.0	1.0
Analyzed chemical composition				
Dry matter	871.5	874.6	874.0	872.0
Organic matter	836.7	839.6	839.0	832.0
Crude protein	149.4	149.8	150.0	151.1
Ether extract	49.7	49.7	65.7	67.7
Crude fibre	37.2	38.7	36.1	37.6
Calculated chemical composition				
Digestible energy (MJ/Kg)	13.7	13.7	13.9	13.9
Lysine	7.1	7.2	9.7	9.6
Threonine	5.6	5.3	6.4	6.4
Methionine + Cystine	5.4	5.5	6.2	7.0
SID Lys [4]	6.0	6.1	8.6	8.6
SID Thr [4]	4.6	4.3	5.5	5.5
SID Methionine + Cystine [4]	4.7	4.8	5.4	5.9
Calcium (Ca)	5.9	5.9	5.7	5.7
Phosphorus (P)	5.4	5.3	5.3	5.0

[1] DHR1 = diet with 100 g dehydrated food residues with meat (DHR1)/kg feed. [2] DHR2 = diet with 80 g dehydrated hotel food residues without meat (DHR2)/kg feed. [3] Premix supplied per kg of diet: 15,000 IU vitamin A (retinyl acetate), 3000 IU vitamin D_3 (cholecalciferol), 37.5 mg vitamin E (DL-α-tocopheryl acetate), 3 mg vitamin K_3, 1.95 mg vitamin B_1 (thiamine nitrate), 3.75 mg vitamin B_2 (riboflavin), 2.7 mg vitamin B_6 (pyridoxine-HCl), 0.027 mg vitamin B_{12} (cyanocobalamin), 22.5 mg niacin (nicotinic acid), 12 mg pantothenic acid (D-pantothenic calcium), 1.2 mg folic acid, 0.075 mg biotin, 35 mg vitamin C (ascorbic acid), 300 mg choline (choline chloride), 1.5 mg iodine (CaI), 100 mg iron ($FeSO_4 \cdot H_2O$), 75 mg manganese (MnO), 135 mg copper ($CuSO_4 \cdot H_2O$), 0.15 mg selenium (Na_2SeO_3), 135 mg zinc (ZnO). Premix also supplied per kg of diet: 4.1 g Ca ($CaCO_3$), 1.3 g P ($CaHPO_4$), 1.18 g Na (NaCl), 1.22 g lysine (L-lysine HCl, 80%) and 400 FTU phytase. mboxtextsuperscript4 Standardized ileal digestible amino acids.

Pigs were housed indoors in individual cages, for both trials, equipped with plastic slatted floor and stainless-steel nipple drinkers and feed troughs. The side panels of the cages were made of stainless steel and high endurance PVC. Environmental conditions were controlled by a ventilation system and a 12 h light:12 h dark light program was implemented. The temperature was maintained at 24 ± 3 °C (FT1; mid-summer 2019) and at 15 ± 1 °C (FT2; winter 2020–2021).

2.3. Performance Parameters and Carcass

In both FT1 and FT2, the average daily body weight gain (ADWG), the average daily feed intake (ADFI) and the feed conversion ratio (FCR) were calculated for the whole experimental period. At the end of each trial, the pigs were sacrificed in a commercial abattoir.

Blood samples were collected at slaughter in heparinized tubes. After chilling at 4 °C for 24 h, carcasses were weighted and dressing percentage was calculated. Subsequently, meat samples were obtained from the loin to determine meat quality indices.

2.4. Determination of Biochemical Parameters in Blood

Aspartate aminotransferase (SGOT-AST) (IU/L), alanine aminotransferase (SGPT-ALT) (IU/L), blood urea nitrogen (BUN) (mg/dL), γ-glutamyltransferase (γ-GT) (IU/L), alkaline phosphatase (IU/L), cholesterol (mg/dL), total proteins (g/dL) and fractions of albumins (g/dL) and globulins (g/dL) were determined in blood samples. Hematological parameters were assessed using an automatic ABX Pentra 400 analyser (Horiba-ABX, Montpellier, France).

2.5. Determination of Physical and Colour Traits in Meat

Meat samples were used to assess muscle pH, color, cooking loss and shear force in both feeding trials. For the determination of pH an electrode was attached in a pH meter (Sentrom 1001 pH System, Rodem, The Netherlands). Afterwards, each sample remained for 30 min in room temperature. Color was determined with a Miniscan XE (Hunter-Lab, Reston, VA, USA) using the Hunter Lab system with L* (Lightness), a* (redness), b* (yellowness) [32]. For each sample three measurements were taken.

Each sample was weighed, placed in specific plastic bags and cooked for 50 min in 80 °C in a water bath. At the end of time samples were left 15 min to cold and weighed again to calculate the percentage of cooking loss. Shear force was measured according to Cason et al. [33]. A Zwick Testing Machine (Model Z2.5/TN1S; Zwick GmbH & Co, Ulm, Germany) equipped with a shear blade (Warner-Blatzler G146; Intron, Grove City, PA, USA). Three strips of each sample with 1cm^2 thick were cut. Peak force values were obtained in N/cm^2.

2.6. Determination of Iron-Induced Lipid Oxidation in Meat

Iron-induced lipid oxidation in the intramuscular fat was carried out according to Terevintho et al. [34]. Two (2) g of minced meat were homogenized in a homogenizer (X 1000D model; CAT, M, Zipperer GmbH, Kumhausen, Germany) with 20 mL of 0.15 M KCl (pH 7.2) for 1 min at 12,000 rpm in a 50-mL centrifuge tube placed inside an ice bath. Samples were centrifuged at 2000× *g* for 10 min (4 °C Half (0.5) mL of the supernatant was mixed with 0.5 mL 0.15 M KCl and 30 μL of 3mM BHT (time point 0). Another 5 mL of the supernatant were mixed with 5 mL of 0.5 mM $FeSO_4$ and 50 μL of 1mM H_2O_2 solution, and were incubated at 37 °C in a water bath, with agitation, for 30, 120 and 300 min (time points 30, 120 and 300). At the end of each incubation time, 1 mL was taken and the oxidation reaction stopped with the addition of 30 μL of 3 mM BHT. MDA measurement for all time points was carried out as follows: 1 mL of TBA–TCA solution (35 mM TBA and 10% TCA in 125 mM HCl) was added and samples were placed in a boiling water bath for 30 min, were cooled in an ice bath for 5 min and left at room temperature for 45 min. Four ml of n-butanol were added and the pink chromogen was extracted by and a centrifugation at 3000× *g* for 10 min. The absorbance of the supernatant was measured at 535 nm (Helios α, Thermo spectronic, Cambridge, UK) immediately. MDA concentration was calculated using its molar extinction coefficient (156,000 M^{-1} cm^{-1}) and results were expressed as mg MDA per kg of wet meat.

2.7. Economic Evaluation of Food Waste

Firstly, the economic evaluation of food waste was carried out using the method of Combs and Romoser (1955) [35]. According to this method, the marginal (maximum acceptable) market value (V) was calculated using the formula:

$$V = a \times x + b \times y + K$$

where, a is digestible energy content of food waste (MJ/kg), b is the sulphur aminoacid-free crude protein of food waste [crude protein-(methionine + cysteine)] (kg/kg), x is the value of digestible energy of food waste (€/MJ), y is the value of sulphur aminoacid-free crude protein of food waste (€/kg) and K is the sum value of sulphur aminoacids, calcium and available phosphorus contained in 1 kg of food waste (€).

Maize and soybean meal were used as prototype feedstuffs for the calculations. The marginal value was calculated separately for FT1 and FT2 due to the differences in the chemical composition between the two food wastes used and the raise in the market prices of maize and soybean meal between the two trials.

Secondly, the V of both food wastes was used as market price in a linear programming software (GL-Feed Formulation, G-Logic S.A., Athens, Greece) to compare the cost of the food waste-containing diets with that of the control diet in both feeding trials. The aim was to calculate the optimum and the maximum allowable dietary food waste content from the economic point of view.

2.8. Statistical Analysis

The SPSS statistical package (version 17.0) (IBM, Armonk, NY, USA) was used to analyze the data that 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 which transforms the variable into a percentile rank and applies inverse-normal transformation to this rank to form a variable consisting of normally distributed z-scores. Normal and transformed data were analyzed afterwards by *t*-test with diet as fixed effect. Pigs was the experimental unit and statistical significance was set at $p < 0.05$.

3. Results

3.1. Growth Performance and Carcass Traits

In FT1, the ADFI tended to be lower and the ADWG was lower ($p < 0.05$) for the DHR1 compared to the C1 treatment. However, the final BW was not affected by the inclusion of food waste material in the pig diets. FCR was similar for both treatments. Moreover, no major differences were detected in the dressing percentage between treatments (Table 4).

Table 4. Effect of diet on average daily feed intake (ADFI), average daily weight gain (ADWG), and feed conversion ratio (FCR) during the first (FT1) and the second (FT2) feeding trial.

FT1	**C1**	**DHR1** [1]	***p*-Value** [3]
Initial BW (kg)	49.73 ± 0.775	50.53 ± 0.883	0.501
Final BW (kg)	98.57 ± 1.694	94.23 ± 2.049	0.119
ADFI (kg/d)	2.78 ± 0.059	2.54 ± 0.100	0.058
ADWG (kg/d)	1.06 ± 0.027	0.95 ± 0.039	0.027
FCR (kg feed/kg gain)	2.63 ± 0.069	2.70 ± 0.141	0.633
Hot carcass weight (kg)	75.12 ± 1.507	72.68 ± 1.511	0.27
Hot carcass DP (%)	79.07 ± 0.556	79.80 ± 0.432	0.321
Cold carcass weight (kg)	73.08 ± 1.464	70.73 ± 1.488	0.275
Cold carcass DP (%)	76.92 ± 0.550	77.65 ± 0.443	0.322
FT2	**C2**	**DHR2** [2]	***p*-Value** [3]
Initial BW (kg)	51.80 ± 0.727	52.20 ± 0.554	0.667
Final BW (kg)	108.75 ±1.491	109.45 ± 1.657	0.757
ADFI (kg/d)	2.91 ± 0.078	3.01 ± 0.097	0.434
ADWG (kg/d)	1.04 ± 0.035	1.04 ± 0.028	0.907
FCR (kg feed/kg gain)	2.82 ± 0.054	2.89 ± 0.063	0.383
Hot carcass weight (kg)	87.45 ± 1.201	87.89 ± 1.669	0.831
Hot carcass DP (%)	80.42 ± 0.406	80.26 ± 0.446	0.8
Cold carcass weight (kg)	84.76 ± 1.234	85.71 ± 1.641	0.649
Cold carcass DP (%)	77.94 ± 0.365	78.27 ± 0.457	0.577

[1] DHR1 = diet with 100 g dehydrated food residues with meat (DHR1)/kg feed. [2] DHR2 = diet with 80 g dehydrated hotel food residues without meat (DHR2)/kg feed. [3] *p*-value of 2-tailed *t*-test for equality of means.

The results of FT2 are presented in Table 4. The 8% inclusion of dried food residues with no meat residues did not affect significantly any of the growth parameters examined.

3.2. Biochemical Parameters Values

In Table 5, the results of the biochemical parameters from food waste inclusion for both trials are presented. In the FT1, the blood cholesterol concentration in DHR1 was significantly higher ($p < 0.001$) compared to C1 group. The blood SGOT/AST levels were also higher in DHR1 compared to C1 group ($p < 0.01$), while SGPT/ALT levels tended to be higher ($p = 0.052$) in DHR1 group. All of the examined blood biochemical parameters were unaffected in the second trial with the exception of globulins that were significantly higher ($p < 0.01$) in DHR2 compared to C2 group.

Table 5. Effect of diets 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, and globulins during the first (FT1) and the second (FT2) feeding trial.

FT1	**C1**	**DHR1** [1]	***p*-Value** [3]
SGOT-AST (IU/L)	245.6 ± 41.78	509.8 ± 65.20	0.003
SGPT-ALT (IU/L)	65.2 ± 4.61	78.0 ± 3.62	0.052
BUN (mg/dL)	12.5 ± 0.52	11.1 ± 0.75	0.14
γ-GT (IU/L)	174.6 ± 16.52	207.1 ± 25.15	0.279
ALP (IU/L)	241.6 ± 44.48	181.4 ± 13.90	0.26
Cholesterol (mg/dL)	76.3 ± 2.84	97.1 ± 4.60	<0.001
Albumins (g/dL)	3.9 ± 0.12	3.8 ± 0.19	0.603
Total protein (g/dL)	7.2 ± 0.14	7.0 ± 0.18	0.272
Globulins (g/dL)	3.3 ± 0.12	3.2 ± 0.13	0.444
FT2	**C2**	**DHR2** [2]	***p*-Value** [3]
SGOT-AST (IU/L)	777.4 ± 179.84	1177.2 ± 184.91	0.139
SGPT-ALT (IU/L)	87.60 ± 9.233	83.20 ± 5.479	0.687
BUN (mg/dL)	10.91 ± 0.625	10.32 ± 0.359	0.421
γ-GT (IU/L)	128.90 ± 18.080	108.8 ± 25.254	0.526
ALP (IU/L)	150.44 ± 11.873	197.6 ± 31.967	0.193
Cholesterol (mg/dL)	87.50 ± 5.714	93.2 ± 3.155	0.394
Albumins (g/dL)	4.08 ± 0.125	3.93 ± 0.106	0.37
Total protein (g/dL)	6.49 ± 0.197	6.80 ± 0.122	0.197
Globulins (g/dL)	2.41 ±0.099	2.87 ± 0.118	0.008

[1] DHR1 = diet with 100 g dehydrated food residues with meat (DHR1)/kg feed. [2] DHR2 = diet with 80 g dehydrated hotel food residues without meat (DHR2)/kg feed. [3] *p*-value of 2-tailed *t*-test for equality of means.

3.3. Meat Quality Measurements

Table 6 presents the color and physical traits of meat for FT1 and FT2. In FT1, the value of pH_{24} was significantly lower ($p < 0.01$) in the DHR1 compared to C1 treatment, whereas all of the other examined traits remained unaffected.

Table 6. Effect of diets on color traits, pH 24 h post-mortem (pH24), cooking loss (%) and shear force values ($100 \times N/cm^2$) of loin during the first (FT1) and the second (FT2) feeding trial.

FT1	**C1**	**DHR1** [1]	***p*-Value** [3]
Color traits [4]			
L*	53.16 ± 0.464	54.23 ±0.521	0.144
a*	5.62 ± 0.196	5.39 ± 0.236	0.461
b*	14.46 ± 0.185	14.26 ± 0.204	0.472
Physical traits			
pH_{24}	5.79 ± 0.017	5.72 ± 0.016	0.007
Cooking loss	34.03 ± 0.592	34.58 ± 0.451	0.469
Shear force	46.72 ± 3.09	49.36 ± 2.16	0.492
FT2	**C2**	**DHR2** [2]	***p*-Value** [3]
Color traits [4]			
L*	52.50 ± 0.359	52.50 ± 0.631	0.993
a*	5.95 ± 0.195	5.88 ± 0.298	0.81
b*	14.32 ± 0.183	14.24 ± 0.217	0.768
Physical traits			
pH_{24}	5.72 ± 0.011	5.72 ± 0.010	0.844
Cooking loss	30.83 ± 0.524	32.66 ± 0.674	0.046
Shear force	25.00 ± 1.667	27.28 ± 1.927	0.384

[1] DHR1, diet with 100 g dehydrated food residues (DHR1)/kg feed. [2] DHR2, diet with 80 g dehydrated hotel food residues (DHR2)/kg feed. [3] *p*-value of 2-tailed *t*-test for equality of means. [4] L*, lightness, a*, redness; b*, yellowness.

In FT2, when pigs fed 8% dried hotel residues with no meat traces, no major differences in the color and physical traits of meat were observed., with the exception of cooking loss which was significantly higher ($p < 0.05$) in DHR2 when compared to C2 treatment.

3.4. MDA Results

The MDA concentration after 300 min of oxidation did not differ among treatments in both trials, as presented in Table 7.

Table 7. Effects of diet on malondialdehyde (MDA) (mg/kg wet meat) concentrations during iron-induced lipid oxidation in the first (FT1) and the second (FT2) feeding trial.

FT1	**C1**	**DHR1** [1]	***p*-Value** [3]
0 min	0.156 ± 0.008	0.152 ± 0.010	0.748
30 min	0.203 ± 0.010	0.224 ± 0.011	0.194
120 min	0.349 ± 0.024	0.300 ± 0.012	0.076
300 min	0.634 ± 0.115	0.430 ± 0.065	0.134
FT2	**C2**	**DHR2** [2]	***p*-Value** [3]
0 min	0.121 ± 0.008	0.122 ± 0.016	0.744
30 min	0.213 ± 0.009	0.206 ± 0.010	0.545
120 min	0.262 ± 0.023	0.295 ± 0.040	0.773
300 min	0.378 ± 0.090	0.447 ± 0.092	0.762

[1] DHR1 = diet with 100 g dehydrated food residues (DHR1)/kg feed. [2] DHR2 = diet with 80 g dehydrated hotel food residues (DHR2)/kg feed. [3] *p*-value of 2-tailed *t*-test for equality of mean.

3.5. Economic Evaluation of Food Waste

The results of the economic evaluation are presented in Table 8. In FT1, the marginal value of the DHR1 waste was 306 €/ton. The cost of the DHR1 diet was slightly higher compared to that of the C1 diet (274 vs. 272 €/ton, respectively), when dietary food waste inclusion was fixed at 10%. The maximum allowable and the optimal dietary food waste inclusion was found to be 11%.

Table 8. Economic approach to the marginal value (V), the maximum allowable and the optimal dietary food waste inclusion level determined by linear programming (LP), in the first (FT1) and the second (FT2) feeding trial.

FT1		**Cost of Diet (€/ton)**	
V_{DHR1} = 306 €/ton	**Inclusion (%)**	**C1**	**DHR1** [1]
Fixed DHR1 level	10	272.0	274.0
Maximum Allowable DHR1 level	11		272.0
Optimal DHR1 level	11		272.0
FT2		**Cost of diet (€/ton)**	
V_{DHR2} = 350 €/ton	**%**	**C2**	**DHR2** [2]
Fixed DHR2 level	8	373.0	391.0
Maximum Allowable DHR2 level	11		485.0
Optimal DHR2 level	7		370.0

[1] DHR1 = diet with dehydrated food residues (DHR1) in FT1. [2] DHR2 = diet with dehydrated hotel food residues (DHR2) in FT2.

In FT2, the findings were somewhat different. The marginal value of the DHR2 waste was higher (350 €/ton) owing mainly to its lower crude protein and digestible energy content in comparison with DHR1, and the increase in the market price of the feedstuffs, in general, during this period. The cost of the DHR2 diet was higher compared to that of the C2 diet (391 vs. 373 €/ton, respectively), when dietary food waste inclusion was fixed at 8%. The maximum allowable dietary food waste inclusion calculated by linear programming was found to be 11% but it severely affected the cost of the DHR2-containing

diet (0.485 €/ton). The optimal dietary food waste inclusion to avoid a great increase in the cost of the diet (compared to the C2 diet) was found to be 7% (Table 8).

4. Discussion

The high quality of meat products in a short period and with the least possible cost are the main goals of the finishing pig sector. From this scope, it is necessary to evaluate the meat quality as long as the growth performance.

In the FT1, after the inclusion of dried hotel residues, pigs were characterized by lower ADWG and ADFI, while the final BW was not affected and FCR was similar between treatments. In a study [19], 40% of a dehydrated food waste (CP = 15.0%, EE = 13.8%) was added in finishing pig diets and pigs consumed less feed compared to control group. The average weight gain was unaffected, but FCR was improved.

In FT2, when food waste with no meat residues was added in pig diets at a level of 8%, no adverse effect was observed in final BW, in ADFI, ADWG, FCR, and dressing percentage. These results are in agreement with another study [36] with the use of 120 g waste from fruit shops (CP = 11.66%, EE = 1.52%) and 50 g from fish shops (CP = 57.92%, EE = 19.10%). This trial resulted in no difference among groups as far as the final BW of pigs and average feed intake and weight gain are concerned. In the aforementioned study, FCR did not differ in pigs consumed control or experimental diet, but a lower dressing percentage in experimental group was noted. Kwak et al. [37] detected no differences in BW, ADWG and dressing percentage, while FCR decreased with increasing dietary food waste (CP = 16.2%, EE = 12.8%) in pigs. Similarly, in a study carried out by Chae et al. [38] comparing 20% and 40% dietary food waste inclusion, ADWG and FCR significantly decreased when dehydrated food waste (CP = 25%, EE = 17.3%) increased from 20% to 40%. The quality, the composition and the processing methods of food waste are important factors to determine the optimal inclusion level in pig diets. However, our findings regarding the effects of dietary dried hotel residues on pigs' performance must be further confirmed in trial with higher number of replicates per treatment.

Serum SGOT-AST was two-fold higher in DHR treatment compared to control in the FT1, while serum SGPT-ALT increased in DHR group. In the FT2, no significant differences in SGOT-AST and SGPT-ALT were detected among treatments. A survey that assessed hematological parameters in pigs in different seasons had detected an increased level of liver SGPT-ALT and SGOT-AST during the summer season but not during the winter season [39], which may explain our findings. The high fat content of the examined food waste in the first trial of the present study may have resulted in a higher blood cholesterol concentration in the DHR1 treatment. However, no such effect was observed in the second trial. Similar results were reported by Giamouri et al. [40] and Cho et al. [41] where broilers fed food waste with high fat content had increased blood cholesterol levels. In contrast, Ramírez-Zúñiga et al. [42] did not observe any change in the concentration of several metabolites, such as cholesterol, when adding 50% and 100 % kitchen and dining waste in the diet of growing pigs.

The variation of the impact of different dietary inclusion levels of food waste on meat characteristics was also assessed. The addition of dried hotel residues either on 10% (DHR1) or in 8% with no meat (DHR2) did not affect the color traits of the meat. The intact lightness indicates that inclusion of food waste did not deteriorate meat color. Nevertheless, the inclusion of 10% led to significant lower pH_{24} in DHR1 treatment. The *post-mortem* pH is an important parameter since it influences other meat characteristics such as meat color and water holding capacity [43]. Moreover, cooking loss was higher in DHR2 treatment in the second trial when pigs fed the no-meat material. Kwak et al. [33] examined the same color parameters, pH, cooking loss and shear force and did not find any effects of a diet containing 25% food waste. In another study [44], a decrease in meat lightness was observed, while pH 24 h *post-mortem* was not affected when different levels of dried hotel residues were added to pig diets.

A positive finding of the present study was the fact that the meat MDA concentration was not affected by the dietary inclusion of dried hotel residues. In both trials, the meat of pigs fed hotel residues exhibited an oxidative stability similar to that of pigs fed the control diet. However, in another study [45], pork loins were shown to be predisposed to rancidity when food waste was added to diets. This is in disagreement with the study of Kouba and Mourot (2011) [46] probably due to the process used to produce the material (food waste) intended to be fed. With regards to this aspect, our results indicate that the entire DHR production process (preservation, transport, sun-drying etc.) did not deteriorate the quality of the final material, particularly with respect to lipid peroxidation which is important when a material is intended to be used as an animal feedstuff. Hence, the present study suggests that meat from pigs fed dried hotel residues are not susceptible to rancidity.

The economic evaluation of the food waste showed that its marginal market price (V) is strongly dependent on the conditions of the feedstuff market in general. The V represents the maximum price above which the dietary use of food waste is not permitted (i.e., cannot be used since it is not economically advantageous). When the feedstuff prices are higher, the V of the food waste is higher (hence, its use is favoured). However, the calculation of V takes into account only the chemical composition of food waste and the market price of maize and soybean meal (as standard feedstuffs), and ignores other important factors such as the level of inclusion, the chemical composition and the market price of the other feedstuffs (particularly the prototypes maize and soybean meal) contained in the diet. Therefore, we exploited the capabilities of linear programming to run different scenarios which could assist to define: (a) the maximum dietary food waste inclusion levels permitted by linear programming to formulate a similar to the control diet (irrespectively of the cost); and (b) the optimal dietary food waste inclusion levels (with respect to cost) using V as the "real" market price. This use of V as market price in the present study was inevitable since the production of food waste was carried out in a small (pilot) scale and there were no sufficient data (production costs etc.) to calculate a representative price. The results showed that the maximum dietary inclusion level of food waste in order to achieve a least-cost balanced diet for finishing pigs was limited to 11% in both trials. In FT1, this maximum level coincided with the optimum dietary level since the cost did not increase compared to the control diet. However, in FT2 it increased dramatically the feed cost and the optimum dietary level was estimated at 7% to obtain a least cost diet. Hence, two conclusions can be drawn here. First, the food waste can be economically advantageous when its market price does not exceed a maximum of 300–350 €/ton. Second, the optimum dietary level of the food waste (for a least-cost diet) used herein may range from 7 to 11%. In both cases, the use is strongly dependent on the chemical composition of the food waste and the market prices of the other feedstuffs contained in a diet for finishing pigs. Further research is necessary to investigate the potential market prices of food waste under large scale production, where the cost will likely decrease.

In addition to all of the above, it must be noted that different food waste materials contain different ingredients that may produce a high variation in their chemical composition; hence, it is not unlikely that the nutritional quality may largely vary from one food waste or one specific waste collection period to another, which may limit their routine use in commercial feeding. The conventional feedstuffs used in pig feeding are also characterized by a variation in the chemical composition. However, this variation is smaller particularly, for base feedstuffs such as maize or soybean meal. The interpretation of the studies with food waste materials should be carried out with care since each food waste can be unique in terms of ingredient and chemical composition. For example, a hotel food waste in Thailand is totally different from a corresponding one in Greece due to differences in culinary practices (raw materials, cooking methods etc.) between these two regions. Therefore, the results from feeding pigs with dietary food waste in Thailand should not be taken granted in Greece. The same stands when comparing food waste materials from different collection periods within a region. Our results depicted differences in the nutritional value of the two food waste materials collected at separate periods indicating that such materials can

be poorly reproduced. Nevertheless, their dietary inclusion in two separate trials gave reproducible results with some small exceptions. This was mainly due to the detailed chemical characterization of the materials prior to diet formulation. Thus, the potential limitations of their use in pig feeding can be adequately addressed. These findings should be further confirmed in future studies with higher dietary food waste inclusion levels.

In conclusion, the dietary inclusion of dried hotel residues affects pig growth performance to a rather small extent, since feed conversion ratio and dressing percentage were not different from those obtained using a commercial finisher diet without food waste. Also, no detrimental effects of feeding dried hotel residues on meat quality traits (color, pH, tenderness and oxidative stability) were observed. The inclusion level of food waste in pig diets was decided in order to avoid a great increase in the dietary ether extract content. However, a fixed ingredient composition and a low production cost of food waste could assure a more stable chemical content and a low market price, respectively, in order to optimize the dietary inclusion levels in pig diets. Overall, our results support the use of dried food residues in pig feeding as long as safety and quality are ensured. Further work is necessary to evaluate the transformation of food waste to animal feed in order to achieve a sustainable product and maintain low feeding costs in pigs.

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References

1. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects 2019*. Available online: http://population.un.org/wpp/ (accessed on 15 December 2021).
2. WHO; FAO. Diet, nutrition and the prevention of chronic diseases. *World Health Organ. Tech. Rep. Ser.* **2003**, *916*, 20.
3. Godfray, H.C.J.; Beddington, J.R.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Pretty, J.; Robinson, S.; Thomas, S.M.; Toulmin, C. Food security: The challenge of feeding 9 billion people. *Science* **2010**, *327*, 812–818. [CrossRef] [PubMed]
4. McGlone, J.J. The future of pork production in the world: Towards sustainable, welfare-positive systems. *Animals* **2013**, *3*, 401–415. [CrossRef] [PubMed]
5. Robinson, T.P.; Pozzi, F. *Mapping Supply and Demand for Animal-Source Foods to 2030*; FAO: Rome, Italy, 2011; ISBN 9789251070413.
6. FAO. *The Future of Food and Agriculture: Trends and Challenges*; FAO: Rome, Italy, 2017.
7. FAO. *Food Wastage Footprint: Impacts on Natural Resources: Summary Report*; FAO: Rome, Italy, 2013.
8. Gustavsson, J.; Cederberg, C.; Sonesson, U.; Otterdijk, R.; McYbeck, A. *Global Food Losses and Food Waste: Extent, Causes and Prevention*; FAO: Rome, Italy, 2011.
9. FAO. *The State of Food and Agriculture 2019. Moving Forward on Food Loss and Waste Reduction*; FAO: Rome, Italy, 2019.
10. Parfitt, J.; Barthel, M.; MacNaughton, S. Food waste within food supply chains: Quantification and potential for change to 2050. *Philos. Trans. R. Soc. B Biol. Sci.* **2010**, *365*, 3065–3081. [CrossRef] [PubMed]
11. Stenmarck, Å.; Jensen, C.; Quested, T.; Moates, G.; Cseh, B.; Juul, S.; Parry, A.; Politano, A.; Redlingshofer, B.; Scherhaufer, S.; et al. *FUSIONS—Estimates of European Food Waste Levels*; IVL Swedish Environmental Research Institute: Stockholm, Sweden, 2016; ISBN 9789188319012.
12. De Boer, I.J.M.; Van Ittersum, M.K. *Circularity in Agricultural Production*; Wageningen University & Research: Wageningen, The Netherlands, 2018.
13. Westendorf, M.L. (Ed.) Food Waste as Swine Feed. In *Food Waste to Animal Feed*; Iowa State University Press: Iowa City, IA, USA, 2000; pp. 69–90.

14. Rohella, R.S.; Panda, S.K.; Das, P.S. Hotel Food Scraps Go to the Animals-Reduces Disposal Cost and Saves Environment. *Am. J. Environ. Prot.* **2015**, *3*, 53–59. [CrossRef]
15. Zu Ermgassen, E.K.H.J.; Phalan, B.; Green, R.E.; Balmford, A. Reducing the land use of EU pork production: Where there's swill, there's a way. *Food Policy* **2016**, *58*, 35–48. [CrossRef] [PubMed]
16. Fairlie, S. *Meat: A Benign Extravagance*; Chelsea Green: Hampshire, UK, 2010.
17. Westendorf, M.L. (Ed.) Food Waste as Animal Feed: An Introduction. In *Food Waste to Animal Feed*; Iowa State University Press: Iowa City, IA, USA, 2000; pp. 3–16.
18. Esteban, M.B.; García, A.J.; Ramos, P.; Márquez, M.C. Evaluation of fruit-vegetable and fish wastes as alternative feedstuffs in pig diets. *Waste Manag.* **2007**, *27*, 193–200. [CrossRef]
19. Myer, R.O.; Brendemuhl, J.H.; Johnson, D.D. Evaluation of Dehydrated Restaurant Food Waste Products as Feedstuffs for Finishing Pigs. *J. Anim. Sci.* **1999**, *77*, 685–692. [CrossRef]
20. Castrica, M.; Tedesco, E.A.D.; Panseri, S.; Ferrazzi, G.; Ventura, V.; Frisio, G.D.; Balzaretti, M.C. Pet Food as the Most Concrete Strategy for Using Food Waste as Feedstuff within the European Context: A Feasibility Study. *Sustainability* **2018**, *10*, 2035. [CrossRef]
21. Garcia, A.J.; Esteban, M.B.; Marquez, M.C.; Ramos, P. Biodegradable municipal solid waste: Characterization and potential use as animal feedstuffs. *Waste Manag.* **2005**, *25*, 780–787. [CrossRef]
22. Westendorf, M.L.; Schuler, T.; Zirkle, E.W.; Hays, V.W.; Wilson, L.L. Nutritional Quality of Recycled Food Plate Waste in Diets Fed to Swine. *Profes. Ani. Sci.* **1999**, *15*, 106–111. [CrossRef]
23. Terpstra, C.; Wensvoort, G. African swine fever in the Netherlands. *Tijdschr. Voor Diergeneeskd.* **1986**, *8*, 389–392.
24. Davies, G. The foot and mouth disease (FMD) epidemic in the United Kingdom 2001. *Comp. Immunol. Microbiol. Infect. Dis.* **2002**, *25*, 331–343. [CrossRef]
25. European Union. Regulation (EC) 1774/2002—Animal by-products not intended for human consumption. *Off. J. Eur. Union* **2002**, *L 273*, 1–95.
26. Dou, Z.; Toth, J.D.; Westendorf, M.L. Food waste for livestock feeding: Feasibility, safety, and sustainability implications. *Glob. Food Secur.* **2018**, *17*, 154–161. [CrossRef]
27. Scientific Opinion of the Panel on Biological Hazards on a request from the Health and Consumer Protection, Directorate General, European Commission on Microbiological Risk Assessment in feeding stuffs for food-producing animals. *Eur. Food Saf. Auth. J.* **2008**, *720*, 1–84.
28. European Feed Manufacturers' Guide (EFMC). A Community Guide to Good Practice for the EU Industrial Compound Feed and Premixtures Manufacturing Sector for Food Producing Animals. Version 1.2. 2014. Available online: https://www.fefac.eu/wp-content/uploads/2020/07/efmc_1_2_e_final.pdf (accessed on 15 June 2021).
29. FSAI. *Commission Regulation 2073/2005/EC of November 2005 on Microbiological Criteria for Foodstuffs*; Food Safety Authority of Ireland: Dublin, Ireland, 2005.
30. European Commission. *Directive 2010/63/EU of the European Parliament and of the Council of the 22 September 2010 on the Protection of Animals Used for Scientific Purposes*; European Commission: Brussels, Belgium, 2010.
31. National Research Council. *Nutrient Requirements of Swine: 10th Revised Edition*; The National Academies Press: Washington, DC, USA, 1998. [CrossRef]
32. CIE (Commission Internationale de l'Eclairage). *Definition D'Un Space de ColourPour Deux Cordones de Cromaticité et la Luminosité. Suppl. 2 to CIE, Publication 15(E-1.3.1) 1971/(TC1-3)*; Centre Internationale de l'Eclairage: Paris, France, 1976.
33. Cason, J.A.; Lyon, C.E.; Papa, C.M. Effect of Muscle Opposition during Rigor on Development of Broiler Breast Meat Tenderness. *Poult. Sci.* **1997**, *76*, 785–787. [CrossRef]
34. Terevinto, A.; Ramos, A.; Castroman, G.; Cabrera, M.C.; Saadoun, A. Oxidative status, in vitro iron-induced lipid oxidation and superoxide dismutase, catalase and glutathione peroxidase activities in rhea meat. *Meat Sci.* **2010**, *84*, 706–710. [CrossRef]
35. Combs, G.F.; Romoser, G.L. *A New Approach to Poultry Feed Formulation*; Pub. No. 226; Maryland Agricultural Experiment Station: Washington, DC, USA, 1955.
36. Márquez, M.C.; Ramos, P. Effect of the inclusion of food waste in pig diets on growth performance, carcass and meat quality. *Animal* **2007**, *1*, 595–599. [CrossRef]
37. Kwak, W.S.; Kang, J.S. Effect of feeding food waste-broiler litter and bakery by-product mixture to pigs. *Bioresour. Technol.* **2006**, *97*, 243–249. [CrossRef]
38. Chae, B.J.; Choi, S.C.; Kim, Y.G.; Kim, C.H.; Sohn, K.S. Effects of feeding dried food waste on growth and nutrient digestibility in growing-finishing pigs. *Asian Australas. J. Anim. Sci.* **2000**, *13*, 1304–1308. [CrossRef]
39. Chmielowiec-Korzeniowska, A.; Tymczyna, L.; Babicz, M. Assessment of selected parameters of biochemistry, hematology, immunology and production of pigs fattened in different seasons. *Arch. Anim. Breed.* **2012**, *55*, 469–479. [CrossRef]
40. Giamouri, E.; Pappas, A.C.; Papadomichelakis, G.; Tsiplakou, E.; Sotirakoglou, K.; Markakis, N.; Galliou, F.; Manios, T.; Zentek, J.; Lasaridi, K.; et al. The food for feed concept. Performance of broilers fed hotel food residues. *Br. Poult. Sci.* **2021**, *62*, 452–458. [CrossRef] [PubMed]
41. Cho, Y.M.; Lee, G.W.; Jang, J.S.; Shin, I.S.; Myung, K.H.; Choi, K.S.; Bae, I.H.; Yang, C.J. Effects of feeding dried leftover food on growth and body composition of broiler chicks. *Asian-Australas. J. Anim. Sci.* **2004**, *17*, 386–393. [CrossRef]

42. Ramírez-Zúñiga, G.; García-Castillo, R.F.; Salinas-Chavira, J.; Vega, A.; Ruiloba, M.H.; Hernández-Bustamante, J.D.; Valdéz-Oyervides, A.; Fuentes-Rodríguez, J.M. Effect of feeding dinning room and kitchen waste on growth performance of growing pigs. *Trop. Subtrop. Agroecosyst.* **2014**, *17*, 241–248.
43. Apple, J.; Kegley, E.; Maxwell, C.; Rakes, L.; Galloway, D.; Wistuba, T. Effects of Dietary Magnesium and Short-duration Transportation on Stress Response, Post Mortem Muscle Metabolism and Meat Quality of Finishing Swine. *J. Anim. Sci.* **2005**, *83*, 1633–1645. [CrossRef]
44. Kjos, N.P.; Øverland, M.; Bryhni, E.A.; Sørheim, O. Food waste products in diets for Growing-finishing pigs: Effect on growth performance, carcass characteristics and meat quality. *Acta Agric. Scand. A Anim. Sci.* **2000**, *50*, 193–204. [CrossRef]
45. Choe, J.; Moyo, K.M.; Park, K.; Jeong, J.; Kim, H.; Ryu, Y.; Kim, J.; Kim, J.M.; Lee, S.; Go, G.W. Meat Quality Traits of Pigs Finished on Food Waste. *Korean J. Food Sci. An.* **2017**, *37*, 690–697. [CrossRef]
46. Kouba, M.; Mourot, J. A review of nutritional effects on fat composition of animal products with special emphasis on n-3 polyunsaturated fatty acids. *Biochimie* **2011**, *93*, 13–17. [CrossRef]