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Incorporation of Guava Seeds Powder into a Commercial Diet Improves the Growth Performance, Nutritional and Quality Characteristics of Muscovy Duck's Meat

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Abstract

Food wastes are valuable resources to be utilized for value-added products in animal feeding for producing meat that is more nutritious and reducing the cost of feeding materials. The effect of the guava seeds powder (GSP) incorporation into Muscovy duck's diet on the growth performance (GP), physicochemical parameters, amino acids and fatty acids composition of duck meat was investigated. The GP and carcass traits (CT) of Muscovy birds were carried out. Chemical composition, physicochemical parameters, amino acids and fatty acids profile were determined in meat. Feed conversion ratio (FCR) and growth hormone (GH) were higher in GSP-diet fed ducks, significantly ($P < 0.05$). Non-significant enhancements in some carcass characteristics, chemical composition, and some physicochemical were observed. Contrariwise, essential amino acids (EAA), and non-essential amino acids (NEAA) were increased with increasing GSP levels by 4.5 and 8.8% in GD10, and 6.3 and 8.5% in GD20, respectively. The essential amino acids index (EAAI %) was 76.56% in GD10 and 79.30% in GD20 when compared with 73.24% in control duck meat (CD). Interestingly, the limiting AAs number was decreased from three in CD duck meat to one in duck meat fed with the GSP-diet at 20%. The majority of unsaturated fatty acids of GSP-diet duck meat was increased with increasing GSP content. Linolenic acid as a ω3 FA was increased by 9.5 and 47.6% in CD10 and GD20, respectively. Incorporating GSP into duck's diet tended to improve GP, some physicochemical, quality-related and nutritional characteristics. The improvements in amino acids and fatty acids profile because of GSP incorporation are promising. Inclusion of certain percentage of GSP in duck's diets not only considered an economically feasible approach to reduce the costs of raising this bird, but it also conserved the physical, chemical and nutritional characteristics which encourage the revalorization of food-processing wastes.

Keywords

Amino acids, Fatty acids, Guava seeds, Meat quality, Muscovy duck

Introduction

After the economic crisis that currently Egypt is facing (starting in November 2016), the feeding of animals and poultry costs has reached approximately 70% of the total production cost. The necessity for improving alternative resources has become necessary. In the developing countries, the skyrocketing price of meat and its products has been a driving force for searching and developing a cheap and sustainable diet for feeding ducks as an alternative source of regular animal proteins [1]. In Egypt, about 18.5 million ducks are bred yearly according to FAO census 2014. However, there are many people, who produce ducks in villages and houses, where estimations are unofficial. As ducks are considered the second common strains of poultry in the world, more attention is given lately to increasing meat production, particularly from ducks, which are the easiest domestic poultry [2] with concerning feeding costs.

Food processing industries are responsible for generating a significant amount of by-products and processing waste, which pose environmental concerns. Indeed, some promising studies considered them as continuous resources of various functional compounds that could be implemented more efficiently [3]. Guava is a seasonal tropical and Mediterranean fruit with a high market share by Egyptians during the summer season. It is widely considered as a rich source of phytochemicals, vitamins, antioxidants, polyphenolics, minerals, dietary fibers and vitamin C. Owing to its nutritional and health benefits, guava could be incorporated in many food products. Interestingly, each fruit contains many small and hard edible seeds, which are thrown out whether being utilized in a fresh form or during the manufacturing process [4-6]. During processing, large amounts of guava residuals or its by-products (including seeds) are generated representing approximately 12-30% of the fruit weight [7, 8]. Produced guava wastes are mostly disposed inappropriately or sent to the landfill causing economic and environmental issues. From sustainability standpoint, the re-use of guava's industrial residuals is necessary to utilize the produced processing residues. Guava seeds (GS) are a cheap source and have no economic value. With high amounts of lignocellulosic materials included, it is considered a suitable and sustainable candidate for animal feeding i.e. ducks [9]. GS contains 7.6-8.22% protein, 13.63-16.2% lipids, 61.40-68.23% fiber, 0.93-1.09% ash, and 7.10-10.27% carbohydrates on dry weight (dw), which could be significantly implemented in feeding manufacturing [8, 10-12]. As for mineral contents, El-Safy et al. [10] recorded that GS powder contained considerable amounts of P, Ca, Mg, K, Cu, Fe, and Zn. Several studies have reported the biological activity of the guava peel, flesh, and leaves, but a few studies were performed on GS characterizations [8, 13-16]. The total phenolic compounds (TPC) of GS ranged from 37.30 to 91.05 g GAE Kg^{-1} [8, 14, 16, 17]. Generally, Carlsen et al. [18] indicated that the ten phenolic and flavonoid compounds were isolated from GS. Interestingly enough, the GS has a higher *in vitro* protein digestibility (up to 92%), which was higher than the recorded protein digestibility in papaya, apple, watermelon, orange, prickly pear, apricot, and paprika seed flours. In addition, the ratio of EAA and the NEAA was 31.33 and 51.56 g 100 g^{-1} protein on dw, respectively [10]. Castro-Vargas et al. [17] reported that the extracted oil from guava seeds (GSO) has reached 19.03% (w/w) and contained a high content of polyunsaturated fatty acids (USFA). Likewise, Nicanor and others [11] represented that the rate of saturated fatty acids (SFA) and un-saturated fatty acids (USFA) in GSO were 30.20 and 69.80%, respectively.

Undoubtedly, it could be suggested that industrial food wastes have potential nutritional value as alternative feedstuffs in poultry feeding [9, 19]. Amazingly, the efficient utilization of food wastes by the ducks established the feasibility of transforming industrial food wastes into a high-quality source of protein and energy for human consumption that may be used up to 50% from the diet itself [9, 20, 21]. From a physiological and health perspective, ducks that are allowed to be fed rich-polyphenols wastes, produced meat that has many pivotal advantages such as flavor, texture, and color as well as improved nutritional characteristics [9, 20, 21]. Hence, the rich-polyphenolics wastes such as GS is presented and a duck's meat production is concerned. The objective of this study was to investigate the effect of GSP incorporation into a Muscovy duck's diet on GP, physicochemical and quality parameters, amino acids and fatty acid composition of the duck meat to initiate the valorization concept and find economical and noncommercial dietary sources for animal feeding.

Materials and Methods

Guava seed preparation

Guava (*Psidium guajava* L.) seeds (GS) were obtained in clean, zipped-plastic bags from Cairo for agricultural processing company in the industrial zone (El-Obour city, Egypt) and were transferred immediately to the analytical laboratory. After removing the asymmetrical parties, GS were allowed to dry at 40-50 °C in an electric-oven dryer until the dried-weight was stable. For the homogenous purpose, the dried-GS was ground using a big coffee grinder, and then the powder was sieved through a 60-mesh sieve. The obtained powder was immediately packed in dark-brown glass jars and kept at -18 ± 1 °C for both analysis and diet formulation. The GSP was characterized, whereas the proximate composition, minerals, amino acids, fatty acids, phytochemical compounds and antioxidant activity were carried out [22] as shown in table 1.

Birds and feeding experiment

Feeding experiment of Muscovy ducks at the Experimental Avian Station, Animal Production Department, Faculty of Agricultural, Benha University, Egypt for 90 d was designed. All experiments and investigations were approved by the Institutional Animal Ethics Committee (IAE) of Benha University, Egypt (Record No. 2016/4/58). One hundred and seventeen broilers of Muscovy ducklings (*Cairina moschata domestica* L.) males (2-weeks of age) were obtained from the El-Wafa Poultry Company, Egypt. Muscovy ducklings were randomly divided into three main groups tagged as group CD, DG10 and DG20 (39 ducklings in each group) which will be fed further with different feeding formulas. Each group was subdivided into 3 sub-groups with 13 ducklings in each replicate. Consequently, each replicate was placed in an individual chamber (approximately 10 m^2). Feed diets (150 kg from each formula) of the experimental groups were prepared at the Experimental Avian Station, Animal Production Department, Faculty of Agricultural, Benha University, Egypt. For adaptation purposes, all birds among groups were allowed

Table 1: Proximate composition, minerals, amino acids, fatty acid, phytochemical compounds and its antioxidant activity of GSP (mean ± SE).

Proximate composition ($g\ kg^{-1}$)

Moisture	Crude protein	Crude fat	Ash	Carbohydrate (soluble)	Crude fiber
56.5 ± 0.4	75.3 ± 1.2	189.3 ± 0.6	12.7 ± 2.5	74.1 ± 5.9	592.1 ± 7.0

Minerals ($g\ kg^{-1}$)

Na	Ca	K	P	Fe	Cu	Mg	Z
0.21 ± 0.06	0.44 ± 0.01	0.62 ± 0.02	0.18 ± 0.01	0.01 ± 0.00	0.08 ± 0.01	0.02 ± 0.01	0.07 ± 0.01

Amino acids ($g\ kg^{-1}$)

EAA▪	
Isoleucine	30.3 ± 0.1
Leucine	61.1 ± 3.0
Lysine	11.2 ± 0.9
Methionine	40.2 ± 0.9
Phenylalanine	34.5 ± 1.3
Threonine	32.7 ± 0.7
Valine	46.3 ± 0.9
Histidine	18.0 ± 0.5
Cystine	21.5 ± 1.1
NEAA▪▪	
Glutamic acid	1188 ± 2.7
Aspartic acid	63.1 ± 0.8
Serine	22.5 ± 1.1
Arginine	95.5 ± 1.9
Alanine	22.5 ± 1.4
Tyrosine	34.1 ± 0.9
Proline	78.0 ± 0.8
Glycine	52.6 ± 1.7
Total EAA	295.8 ± 4.3
Total NEAA	487.1 ± 67
EAA/NEAA	0.61 ± 0.05

▪: Essential Amino Acids
▪▪: Nonessential Amino Acids

Fatty acid ($g\ 100\ g^{-1}$)

Palmitic acid C16:0	77.7 ± 2.5
Palmitoleic acid C16:1	0.6 ± 0.1
Margaric acid C17:0	0.8 ± 0.1
Heptadecenoic acid C17:1	0.1 ± 0.1
Stearic acid C18:0	44.4 ± 1.9
Oleic acid C18:1	102.3 ± 2.1
Linoleic acid C18:2	754.1 ± 19.2
Linolenic acid C18:3	2.5 ± 0.1
Arachidic acid C20:0	5.2 ± 0.2
Gadoleic acid C20:1	3.1 ± 0.4
Behenic acid C22:0	1.1 ± 0.1
Lignoceric acid C24:0	6.7 ± 0.8
SFA	135.9 ± 5.4
USFA	869.4 ± 20.9
USFA/SFA	6.39 ± 0.23

Phytochemical compounds and its antioxidant activity

TPC [$mg\ GAE\ g^{-1\ dw}$]	82.56 ± 0.93
TF [$mg\ g^{-1\ dw}$]	0.38 ± 0.02
TFL [$mg\ g^{-1\ dw}$]	0.21 ± 0.01
DPPH [$\mu mol\ of\ TE\ g^{-1\ dw}$]	12.47 ± 0.28
ABTS [$\mu mol\ of\ TE\ g^{-1\ dw}$]	12.82 ± 0.11
Anthocyanins [$mg\ g^{-1\ dw}$]	0.03 ± 0.01
Carotenoids [$mg\ g^{-1\ dw}$]	2.22 ± 0.25
Chlorophyll a [$mg\ g^{-1\ dw}$]	50.5 ± 0.28
Chlorophyll b [$mg\ g^{-1\ dw}$]	11.79 ± 0.5
Ascorbic acid [$mg\ g^{-1\ dw}$]	1.76 ± 0.01

to receive the basal diet (Table 2) for 3 d before the beginning of the experimental trial. At the beginning of the experimental trial, the control group (CD) birds fed on a basal diet. The DG10-birds were fed on a basal diet that had its yellow corn partially replaced by 10% GSP. The DG20 fed on a basal diet that had its yellow corn partially replaced by 20% GSP (Table 2). Muscovy ducklings were housed in an air-conditioned room, kept in standard conditions with light and dark cycles (23 h light and 1 h dark), and maintained at an ambient temperature of 25 °C. During the trial, the individual duck body weight and diet consumption for the whole replicate were recorded weekly then the diet conversion ratio (FCR) was calculated only at the end of the experimental period.

Table 2: Ingredients and nutritional value of the duck's basal diet and formulated GSP-experimental diets.

Ingredient	g kg^{-1}		
	Basal diet	DG10	DG20
Yellow corn grains	668	568	468
Soybean meal, 44%	300	300	300
Guava seed	0.0	100	200
Dicalcium phosphate	12	12	12
Sodium chloride	3.2	3.2	3.2
Limestone, pulverized	14	14	14
Vitamin premix [a]	1	1	1
Mineral premix [b]	1	1	1
DL-methionine	0.3	0.3	0.3
L-lysine HCl	0.5	0.5	0.5
Total	1000.00	1000.0	1000.0
Calculated analysis			
Curd protein (g kg^{-1})	185	185	185
MEn (k cal/kg)	2836.0	2759.6	2683.2
Crude fiber (g kg^{-1})	36.6	65.0	94.0
Crude fat (g kg^{-1})	14.4	23.0	32.1
Calcium (g kg^{-1})	9.0	9.1	9.2
Avail. Phosphorus (g kg^{-1})	6.0	6.1	7.0
Methionine (g kg^{-1})	3.0	3.0	3.0
Lysine (g kg^{-1})	10.0	10.0	10.0

MEn: Nitrogen-corrected apparent metabolisable energy; a: The vitamin mixture supplied the following vitamins (per kg diet): vitamin A 4400000IU; Vitamin D 72000 IU; vitamin E 14400 IU; Vitamin K 2000 IU; Cobalamin 640 mg; thiamine, 612 mg; riboflavin, 3000 IU; calcium pantothenate, 4896 mg; niacin, 12160; pyridoxine, 612 mg; folic acid, 1.5 mg; choline chloride, 260 g, b : The mineral mixture supplied (mg per kg diet): Mn, 64.5; Zn, 33.8; Fe, 100; Cu, 8; I, 640; Co, 190; Se, 8, as support.

Slaughter and meat samples handling

After 90 days of feeding, all birds were slaughtered by the Islamic method at the abattoir of the Animal Production Department, Faculty of Agricultural, Benha University. Birds were deprived of food, but provided with clean drinking water 12 hours before slaughtering. During slaughtering, blood samples were collected from birds (i.e. 9 random ducks per replicate) for determining GH as described previously [23]. Eviscerated and plucked carcasses were weighed after removing the feet and head to obtain ready to cook carcasses (RCC). Breasts, legs, abdominal fat and Giblet of each duck were weighed then the meat was separated from the bones immediately and weighed to evaluate slaughter traits, meat composition, and quality parameters. Equal appropriate meat portions from breasts and legs of each group were similarly taken from the same place of each carcass and minced using meat mincers (SIEMENS, type CNCM11ST Germany) then subjected immediately to proximate chemical analyses.

Proximate chemical composition

The fresh minced Muscovy duck's meats were subjected to the proximate chemical analysis including moisture (method No. 934.01), crude protein (method No. 990.03), crude lipids (method No. 920.39) and ash contents (No. 923.03) according to methods of A.O.A.C [24]. Accordingly, the caloric value (kcal 100 g^{-1}) fresh weight had been calculated relatively according to the obtained results of the proximate chemical composition.

Determination of physicochemical traits

Total volatile nitrogen (TVN) and thiobarbituric acid (TBA) were determined according to the method described by Harold et al. [25] The results of TVN were expressed as mg TVN 100g^{-1} fresh meat (mg TVN 100 g^{-1}). The Thiobarbituric acid was spectrophotometrically determined at 538 nm using a digital spectrophotometer (model 599 Automatic Scanning Spectrophotometer, USA). The TBA values were calculated by multiplying the absorbance by the factor (7.8) and the results were represented as mg of malonaldehyde kg^{-1} fresh meat (mg MDA kg^{-1}).

Determination of meat quality parameters

The pH values of duck meat were measured by using a digital pH meter (model SA 210) according to the method [24]. The Water holding capacity (WHC) of minced duck meat was measured by the mechanical pressing method according to Trout [26]. The wet area was measured using a compensatory planimeter (Tamaya Technics Inc., Tokyo, Japan) and the percent of absorbed water was calculated based on sample weight and moisture content. The cooking loss was calculated after the cooking of aluminum foil-wrapped minced meat for 15 minutes under live steam injections according to Liao et al. [27] with minor modifications. Color analysis consisting of lightness (L*), redness (a*) and yellowness (b*) was performed by Hunter Lab Color Flex EZ (Hunter Lab Reston, VA, USA). The results were integrated by a Universal Software V 4.10 according to Kwon et al. [28] the pigment of minced meat was determined according to Shehata [29]. The obtained values were used directly as a comparative measure of the pigment concentration.

Determination of amino acids

The amino acids profile was measured on the precipitated protein from defatted duck meat samples (three duck meat samples from each replicate were collected similarly and pooled together then defatted by hexane, HPLC grade). Consequently, acid-hydrolysis by HCL (6.0 N) at 110 °C under vacuum in sealed ampoules for a period of one day was achieved. Quantitative determination of amino acids in triplicate for each group was carried according to A.O.A.C. [30].

Determination of fatty acids composition

Extraction procedure: Fatty acids were extracted according to Aldai et al. [31]. Briefly, appropriate samples were flushed with N_2, shaken for 10 minutes, and saponificated. Reaction mixtures were diluted with 0.5% NaCl and petroleum spirit was added. The non-saponifiable matters were separated and discarded. After neutralization of KOH fraction, petroleum spirit was added twice, samples were centrifuged and the top layer was transferred to clean screw-cap glass tubes. Centrifugation and layer transference steps were repeated again and 100 µL of a water scavenger - 2,2-dimethoxypropane were added then vortexed. Sample were derivatized according to Aldai et al. [31]. The gas liquid chromatography equipped with a dual flame ionization detector was used to analyze the methyl esters of fatty acids (FAs) obtained from duck fats. For injection, diluted samples in 1 µl n-hexane were injected into GLC column under an optimized temperature and gas flow rate program. Results were evaluated with a conventional integrator program (Saturn GC Workstation Software ver., 5.51).

Statistical analysis

The statistical analysis was carried out using a SPSS program with a one-way analysis of variance (ANOVA) regarding to the experimental design under a significance level of 0.05. For mean comparisons among treatments, the Duncan test was performed according to Steel et al. [32].

Results and Discussion

GP and carcass characteristics of Muscovy ducks

The effects of GSP incorporation at different levels (10 and 20%) into Muscovy duck's diet on GP, physicochemical and quality parameters, as well as amino and fatty acids composition of duck meat, was carried out. The GP such as FCR and GH, and carcass characteristics such as the weight of RCC, breast, legs, giblets, abdominal fat % and carcass yield % of Muscovy ducks fed GSP-diet were investigated and data were illustrated in table 3. The FCR, GH and RCC were significantly increased (P < 0.05) in DG10, and DG20 when compared to CD ducks. The FCR reflects that DG10, and DG20 yielded increased carcass weight by 2 and 3% when compared to CD ducks. Correspondingly, the breast, legs, giblets and abdominal fats yield % were slightly increased in DG10 and DG20 when compared with CD ducks. Actually, new feeding formulas (Table 2) enhanced the FCR, GH and RCC significantly; being a positive effect of the GSP addition. Indeed, the most noted changes in the CT were not significantly different as a little increase was observed in individual CT (illustrated by 2 and 3% in carcass yield in DG10 and DG20, respectively). Similar results had been discussed previously [21, 33-35]. In the same context, feeding food-processing wastes resulted in a valuable improvement in FCR and GH in ducks as similarly indicated previously in ducks [20, 21, 28, 35-37]. This might be due to enhancing the GP and strengthening the immunity as observed by Giri et al. [38] by using guava leaves whereas no available data on using GSP in poultry diets were recorded. GSP contains phenolics, antioxidants and bioactive derivatives, which might improve the metabolism [34, 36].

Table 3: Growth performance (GP) and carcass traits (CT) characteristics of Muscovy ducks fed on basal and basal diet partially replaced by GSP after 90 d (mean ± SE).

GP and CT	Treatments		
	CD	DG10	DG20
Feed conversion ratio (FCR)	3.82 ± 0.09 [c]	3.64 ± 0.03 [a]	3.71 ± 0.05 [b]
Growth hormone (ng ml^{-1})	0.06 ± 0.01 [a]	0.10 ± 0.02 [b]	0.12 ± 0.07 [b]
Ready to cook carcass (RCC) (kg)	2.38 ± 0.12[a]	2.78 ± 0.16[c]	2.52 ± 0.24[b]
Breasts (g kg^{-1})	577.8 ± 3.5[a]	572.3 ± 8.9[a]	594.6 ± 11.7[a]
Legs (g kg^{-1})	422.2 ± 3.5[a]	427.7 ± 7.6[a]	405.4 ± 10.4[a]
Giblets (g kg^{-1})	33.1 ± 0.6 [a]	36.4 ± 0.9 [b]	39.2 ± 0.8 [c]
Abdominal fat (g kg^{-1})	8.0 ± 0.2 [b]	9.1 ± 0.2 [c]	7.5 ± 0.2 [a]
Carcass yield* (g kg^{-1})	734.8 ± 8.0 [a]	750.0 ± 10.1 [a]	757.2 ± 5.2 [a]

[a, b, c]Means in the same row with different letter significantly differ at P < 0.05. Normal growth hormone reference = 0.06 - 5.0 ng ml^{-1}, *: The whole carcass meat without bones, (n = 27)

Proximate chemical composition of Muscovy duck meats

As presented in table 4, the proximate composition of the raw meat of Muscovy ducks fed the diet incorporated GSP for 90 days. No significant difference (P > 0.05) was found in chemical composition and caloric value among all duck meat samples. The moisture content ranged from 72.46 to 73.03% in DG10 and CD, respectively. Slight increases of crude protein, crude lipids, and ash contents were remarked in DG20 whereas the caloric value was presented accordingly. Regarding the meat chemical composition, the analysis confirmed that adding GSP had no significant impacts on the meat chemical composition. The unusual change in chemical composition may be subject to some factors such as diet, genetic and environmental factors [39]. Accordingly, a positive increase in the caloric value has been recorded by 2.2% in DG10 and 1.2% in DG20 meat when compared to the CD duck meat (Table 4). As recently reviewed, feeding the ducks on diet containing a valuable amount of phenolics, antioxidants and bioactive derivatives could improve the metabolism and weight gain as well as meat chemical composition and its relative quality [8, 10, 20, 21, 34, 36, 40]. However, the observed positive change is considered as a good indicator for increasing GSP in poultry

Table 4: Proximate chemical composition of minced Muscovy duck meat fed on basal and basal diet partially replaced by GSP after 90 d (mean ± SE).

Chemical composition (g kg^{-1})	Treatments		
	CD	DG10	DG20
Moisture content	730.3 ± 2.4[a]	724.6 ± 1.8[a]	728.1 ± 1.5[a]
Crude protein content [dw]	782.7 ± 16.1[a]	782.1 ± 15.2[a]	788.0 ± 03.8[a]
Crude lipids content [dw]	107.2 ± 4.6[a]	108.2 ± 2.8[a]	111.8 ± 1.7[a]
Ash content [dw]	55.9 ± 0.4[a]	56.4 ± 1.4[a]	58.3 ± 1.4[a]
Caloric value kcal kg^{-1} [fw]	1165.2 ± 12.2[a]	1191.0 ± 13.3[a]	1178.8 ± 14.0[a]

[a,b,c]Means in the same row with different letter significantly differ at P < 0.05. dw: dry weight, fw: fresh weight, (n = 27)

diet, which warrants designing further investigations.

Physicochemical properties of Muscovy duck meats

The TVN and TBA of raw meat of Muscovy ducks fed the diet incorporated GSP after 90 days are presented in table 5. Obviously, no significant differences (P > 0.05) were found among all duck meats in either TVN or TBA contents. The TVN ranged from 12.45 to 13.27 mg TVN 100 g^{-1} in CD and DG20, respectively. In addition, TBA recorded values in the range of 0.32 – 0.36 mg MDA kg^{-1} in DG20 and CD, respectively. Assessing the freshness tests of duck meat to understand the GPS impact on meat quality recorded no significant changes in TVN and TBA (Table 5). However, an increase of TVN had been noticed in ducks' meat fed the diet incorporated GSP, which recorded a little increase in protein content. On the contrary, no significant decrease in TBA content was remarked in fed ducks' meat on diet incorporated GSP, which may reflect that GSP phenolics reduced the lipid deterioration due to its antioxidant content. These results are in agreement with the previous studies [20, 21, 28, 41]. The quality parameters including pH, WHC, cooking loss, pigment, and color have been illustrated in table 5. The pH value ranged from 5.78 to 5.85 in duck meat with no significant difference (P > 0.05) among the treatments. No significant difference (P > 0.05) was found in WHC among all duck meat samples. Meanwhile, 3.4 and 6.2% improvements in WHC have been noticed in DG10 and DG20 when compared to CD meat, respectively. With relation to the results of the WHC in Muscovy duck meat, cooking loss tends to decrease with the increase of the WHC. The cooking loss ranged from 23.01 to 25.05% in DG20 and CD, respectively. As previously, mentioned 5.7 and 8.15% of improvement have been found in the cooking loss in fed ducks' meat on GSP. The pigment content of duck meat was determined to study the effect of adding GSP to the diet on meat pigment. The pigment was in the range of 1.99-212 as OD of meat extract (even red pigment that related to muscles hemoglobin were increased by 2 and 6.5% in DG20 and CD, respectively). In the same criteria, minor improvement were found in duck meat quality regarding pH, WHC, cooking loss, pigment and CIE color (Table 5) may be due to the significant changes in FCR and GH [4]. Increasing the FCR and GH is considered as a good index of the digestive system performance and good vitality of ducks. Controversial, no significant difference (P > 0.05) was found among all duck meat even though a little improvement had been remarked. This may be due to the low level of GPS whereas increasing active ingredients correlated positively with improving the meat quality as mentioned [20, 21, 28].

Table 5: Physicochemical parameters of minced Muscovy duck meat fed on basal and basal diet partially replaced by GSP after 90 d (mean ± SE).

Items	Treatments		
	CD	DG10	DG20
TVN (mg TVN kg^{-1}) fw	124.5 ± 8.4 a	130.2 ± 3.8 a	132.7 ± 2.7 a
TBA (mg MDA kg^{-1}) fw	0.36 ± 0.02 a	0.34 ± 0.02 a	0.32 ± 0.06 a
pH	5.78 ± 0.1 a	5.80 ± 0.1 a	5.85 ± 0.05 a
WHC	44.60 ± 0.72 a	43.10 ± 1.22 a	41.83 ± 0.65 a
Cooking loss %	25.05 ± 1.65 a	23.62 ± 0.83 a	23.01 ± 1.09 a
Pigment	1.99 ± 0.11 a	2.03 ± 0.21 a	2.12 ± 0.18 a
CIE L*	47.43 ± 0.71 a	49.00 ± 1.15 a	49.43 ± 1.37 a
a*	13.73 ± 0.8 a	14.27 ± 0.68 a	14.40 ± 0.78 a
b*	4.13 ± 0.60 a	4.60 ± 0.1 ab	5.47 ± 0.60 b

a,b,c Means in the same row with different letter significantly differ at P <0.05, fw: fresh weigh, (n = 27)

Amino acids content in duck protein

The amino acids composition of differently treated duck's meat protein was presented in table 6. Evidently, there are increases in the total amounts of AA in GSP fed-ducks and the increases positively related the increasing of GSP in the diets. This finding corresponds, not only with the total EAA but also to the total NEAA contents when compared with control. The percent of increases were 5.5 and 8.6% in the total AA, 4.5 and 8.7% in the total EAA and 6.3 and 8.5% in the total NEAA for DG10 and DG20, respectively. Amino acids analysis revealed a valuable increase in total AA's and EAA's with increasing GSP levels which reflect GSP effects on increasing amino acids content of meat protein (Table 6). The obtained results confirmed the benefits of the GSP which

Table 6: Amino acid composition of (g g-1 N) of minced Muscovy duck meat fed on basal and basal diet partially replaced by GSP after 90 d compared with amino acid composition in standard protein (FAO, 1970) (mean ± SE).

Amino acid	Treatments			Hen's egg (FAO, 1970)
	CD	DG10	DG20	
EAA*				
Isoleucine	0.261 ± 0.033 a	0.272 ± 0.091 a	0.291 ± 0.009 a	0.393
Leucine	0.430 ± 0.081 a	0.459 ± 0.027 a	0.463 ± 0.007 a	0.551
Lysine	0.365 ± 0.074 a	0.382 ± 0.019 a	0.409 ± 0.012 a	0.436
Methionine	0.169 ± 0.002 a	0.177 ± 0.005 b	0.183 ± 0.006 b	0.210
Phenylalanine	0.232 ± 0.070 a	0.240 ± 0.019 a	0.264 ± 0.014 b	0.358
Threonine	0.245 ± 0.001 a	0.256 ± 0.002 b	0.263 ± 0.007 c	0.320
Valine	0.301 ± 0.051 a	0.303 ± 0.011 a	0.319 ± 0.011 a	0.428
Histidine	0.135 ± 0.011 a	0.149 ± 0.014 a	0.140 ± 0.019 a	0.152
Cystine	0.143 ± 0.012 a	0.145 ± 0.014 a	0.151 ± 0.009 ab	0.152
NEAA**				
Glutamic acid	0.814 ± 0.008 a	0.851 ± 0.008 b	0.879 ± 0.009 c	0.796
Aspartic acid	0.518 ± 0.031 a	0.541 ± 0.011 ab	0.561 ± 0.011 b	0.601
Serine	0.219 ± 0.042 a	0.211 ± 0.002 a	0.204 ± 0.016 a	0.478
Arginine	0.370 ± 0.011 a	0.381 ± 0.021 a	0.393 ± 0.012 a	0.381
Alanine	0.301 ± 0.005 a	0.418 ± 0.015 a	0.408 ± 0.024 a	0.370
Tyrosine	0.219 ± 0.096 a	0.225 ± 0.011 a	0.235 ± 0.022 a	0.260
Proline	0.244 ± 0.004 a	0.238 ± 0.009 a	0.257 ± 0.014 a	0.260
Glycine	0.315 ± 0.008 a	0.323 ± 0.011 a	0.318 ± 0.012 a	0.207
EAA*	2.282 ± 0.029 a	2.384 ± 0.016 b	2.482 ± 0.032 c	3.000
NEAA**	2.999 ± 0.019 a	3.188 ± 0.017 b	3.255 ± 0.017 c	3.353
Total AAs	5.281 ± 0.045 a	5.573 ± 0.059 b	5.737 ± 0.049 c	6.353

*: Essential amino acids **: Non-essential amino acid (n = 3)

contains functional peptides [8, 11, 40], phenolics, antioxidant and dietary fiber [7, 17, 42], and rich in amino acids as well [3, 43]. The expressed bioactive compounds from GSP improved the meat quality and AA's content in treated duck meat [33, 44]. These improvements had been noticed with increasing GSP levels, which may be a good indicator to increase the GSP in duck's diet to maximize the benefits and to reduce the diet cost, however further investigation is required. The nutritional values of minced Muscovy duck meat proteins fed on GSP diets are given in table 7. It was noticed that increasing GSP levels in the duck's diet resulted in significant increases of the EAA and NEAA (g g^{-1} N). Contrariwise, the relative EAA: NEAA; EAA: protein and NEAA: total AA ratios were not dramatically changed (P > 0.05). In this context, the EAAI% accordingly increased significantly from 73.24% in CD to 76.56% in DG10 and 79.30% in DG20-duck's meat protein, respectively. These values exceeded those reported in the standard proteins in hen's eggs and beef (FAO, 1970). Data in table 7, illustrated the significant increases in EAA and NEE in GD10 and GD20 which may be due to the increase of metabolism and protein content in duck meat. Also, the small increases in the relative ratios of EAA to NEAA, EAA to total protein and NEAA to Total AA have manifested the impact of good FCR and increased GH which may improve the protein quality rather than protein quantity [44]. Correspondingly, increasing the EAAI% would be an encouraging factor for using such food processing wastes (i.e. GSP) in animal diets to improve the meat's nutritional value and quality based characteristics as noticed in other studies [3, 11, 33]. Assessment of the individual AAs concentrations are presented in table 8. However, for determining the protein quality two categories are very important, the AA score that depends on calculating mg of individual AA in one gram of tested protein to mg of EAA in a required pattern is one of them. Scores for tested protein as well as those for different FAO patterns [Hen's egg FAO, 1970] are presented in table 8. The obtained results indicated that AA scores for each EAA of duck samples were higher than AA scores of each EAA of the standard protein (Hen's egg score, FAO, 1970) except for valine, isoleucine and phenylalanine that exhibited lower score values when compared to the standard protein. Although differing greatly, the scores for other essential AA's such as threonine, leucine, tyrosine, histidine and lysine matched or exceeded the corresponding score of the standard protein. Data in table 9, illustrated the certain AA's of different fed Muscovy ducks (either CD or GSP-diet fed meats) and compared to safe suggested amounts of AA patterns as mg g^{-1} protein (FAO, 1985). In regards to limiting amino acids, it has been noticed that phenylalanine is the most deficient and the first limiting AA in meat protein CD, DG10 and DG20. The second limiting AA in CD and DG10 was valine, while it was not that deficient in DG20. The third limiting AA was threonine in CD only, while it was not that deficient in DG10 or DG20 proteins. Increasing the individual AA scores and partially compensating limiting EAA in DG10 and DG20 trended the adding of GSP to duck diet and improving the AA's composition of duck meat (Table 8 and 9). These results are in accordance with Muhlisin et al. [36],

Table 7: The nutritional evaluation of minced Muscovy duck meat fed on basal and basal diet partially replaced by GSP after 90 d proteins (mean ± SE).

Items	Nutritional calculations					
	EAA g/16 N	NEAA g/16 N	EAA: NEAA Ratio	EAA: Protein Ratio	EAA: Total AA Ratio	EAAI %
CD	36.515 ± 0.792 [a]	47.988 ± 1.072 [a]	0.761 ± 0.021 [a]	0.365 ± 0.035 [a]	0.432 ± 0.017 [a]	73.240 ± 0.75 [a]
DG10	38.150 ± 0.695 [b]	51.016 ± 1.211 [ab]	0.748 ± 0.017 [a]	0.381 ± 0.029 [a]	0.428 ± 0.011 [a]	76.557 ± 0.61 [b]
DG20	39.709 ± 0.191 [c]	52.076 ± 1.051 [b]	0.763 ± 0.046 [a]	0.397 ± 0.031 [a]	0.433 ± 0.009 [a]	79.298 ± 0.99 [c]
Egg (FAO, 1970)	44.368	47.04	0.937	0.464	0.484	100.00
Beef (FAO, 1970)	42.724	57.276	0.746	0.427	0.427	79.55

EAA: NEAA: Ratio of essential amino acids to nonessential amino acid.
EAA: Protein Ratio: Ratio of essential amino acids to 100 g protein.
NEAA: Total AA Ratio: Ratio of essential amino acids to total amino acid.
EAAI %: Essential amino acids index according to FAO recommendation.
(n = 3).

Table 8: Assessment of individual amino acids of minced Muscovy duck meat fed on basal and basal diet partially replaced by GSP after 90 d compared to references essential amino acids in hen's egg protein [mg individual AA g^{-1} TEAA], (mean ± SE).

EAAs	Treatments			Hen's egg score (FAO, 1970)
	CD	DG10	DG20	
Threonine	107.42 ± 0.25 [a]	111.97 ± 1.08 [b]	115.12 ± 1.22 [c]	110.42
Valine	131.91 ± 0.19 [a]	132.96 ± 0.84 [a]	139.61 ± 1.12 [b]	147.69
Isoleucine	114.42 ± 1.46 [a]	119.31 ± 0.44 [b]	127.36 ± 0.76 [c]	135.61
Leucine	188.59 ± 1.77 [a]	201.19 ± 0.56 [b]	202.94 ± 0.55 [c]	190.13
Phenylalanine	101.82 ± 1.22 [a]	105.32 ± 0.74 [b]	111.82 ± 0.51 [c]	123.53
Lysine	159.90 ± 0.94 [a]	167.25 ± 0.62 [b]	179.15 ± 0.47 [c]	150.45
Histidine	59.63 ± 0.42 [a]	65.43 ± 0.81 [c]	61.23 ± 0.41 [b]	52.45
Cystine	62.63 ± 0.61 [a]	63.68 ± 0.33 [a]	66.13 ± 0.22 [b]	52.45
Methionine	74.18 ± 0.19 [a]	77.68 ± 0.28 [b]	80.13 ± 0.26 [c]	72.46

$$\text{Amino acid score} = \frac{\text{mg amino acid in 1 g protein}}{\text{mg amino acid suggested by FAO/WHO}} \times 100, (n=3)$$

Table 9: Scores of essential amino acids to limiting the three essential amino acids responsible for limiting the quality of protein of minced Muscovy duck meat fed on basal and basal diet partially replaced by GSP after 90 d (mean ± SE).

Amino acid	Treatments			Safe suggested amount of amino acid pattern (FAO, 1985)*
	CD score	DG10 score	DG20 score	
Threonine	**98.06 ± 0.24ᵃ**	102.21 ± 0.25ᵇ	105.09 ± 0.77ᵇ	40
Valine	**96.33 ± 0.49ᵃ**	**97.10 ± 0.34ᵃ**	101.96 ± 0.74ᵇ	50
Isoleucine	104.45 ± 0.15ᵃ	108.92 ± 0.18ᵇ	116.26 ± 0.28ᶜ	40
Leucine	98.38 ± 0.48ᵃ	104.95 ± 0.75ᵇ	105.86 ± 0.75ᵇ	70
Phenylalanine	**77.47 ± 0.44ᵃ**	**80.12 ± 0.18ᵇ**	**88.10 ± 0.42ᶜ**	48
Lysine	104.26 ± 0.21ᵃ	109.06 ± 0.36ᵇ	116.81 ± 0.58ᶜ	56
Histidine	102.82 ± 0.75ᵃ	113.77 ± 0.32ᶜ	106.47 ± 0.81ᵇ	21
Cystine	103.95 ± 0.25ᵃ	115.70 ± 0.40ᶜ	109.76 ± 0.70ᵇ	22
Methionine	123.12 ± 0.41ᵃ	128.92 ± 0.26ᵇ	132.99 ± 0.37ᶜ	22
First limiting AA	Phenylalanine	Phenylalanine	Phenylalanine	-
Second limiting AA	Valine	Valine	-----	-
Third limiting AA	Threonine	-----	-----	-

* EPR (1985) (*n*=3)

$$\text{Amino acid score according to FAO (1985)} = \frac{\text{mg amino acid in 1 g protein}}{\text{mg amino acid suggested by FAO/WHO}} \times 100$$

Table 10: Fatty acids composition of minced Muscovy duck meat fed on basal and basal diet partially replaced by GSP after 90 d (mean ± SE).

Fatty acid	Fatty acid g kg^{-1}		
	CD	DG10	DG20
Myristic acid (C14:0)	8.3 ± 1.0ᵃ	12.6 ± 0.6ᶜ	10.2 ± 0.5ᵇ
Palmitic acid (C16:0)	229.9 ± 7.8ᵃ	251.5 ± 0.2ᶜ	244.0 ± 2.7ᵇ
Palmitoleic acid (C16:1)	28.5 ± 0.9ᵃ	36.8 ± 0.9ᶜ	33.2 ± 0.3ᵇ
Margaric acid (C17:0)	3.1 ± 0.7ᵃ	5.2 ± 0.1ᵇ	5.7 ± 0.2ᶜ
Heptadecenoic acid (C17:1)	3.6 ± 0.1ᵃ	5.1 ± 0.1ᵇ	6.2 ± 0.1ᶜ
Stearic acid (C18:0)	63.7 ± 5.7ᵃ	60.5 ± 4.1ᵃ	63.0 ± 0.7ᵃ
Oleic acid (C18:1)	418.3 ± 1.4ᵇ	419.1 ± 1.5ᵃ	410.0 ± 10.6ᵃ
Linoleic acid (C18:2)	220.5 ± 0.9ᵇ	182.4 ± 2.4ᵃ	187.1 ± 0.6ᵃ
Linolenic acid (C18:3n3)	10.5 ± 0.0.6ᵃ	11.5 ± 0.1ᵇ	15.5 ± 0.9ᶜ
Arachidic acid (C20:0)	1.9 ± 0.1ᵃ	3.2 ± 0.2ᵇ	6.1 ± 0.4ᶜ
Gadoic acid (C20:1)	6.9 ± 0.1ᵃ	6.6 ± 0.0.4ᵃ	10.7 ± 0.5ᵇ
Behenic acid (C22:0)	0.05 ± 0.0ᵃ	0.3 ± 0.1ᵇ	6.1 ± 0.1ᶜ
Unknown	4.7 ± 0.2ᵃ	5.2 ± 0.3ᶜ	2.2 ± 0.2ᵇ
Total SFA	307.0 ± 7.8ᵃ	333.3 ± 4.5ᵇ	335.1 ± 3.7ᵇ
Total USFA	688.3 ± 9.8ᵇ	661.5 ± 10.7ᵃ	662.7 ± 8.8ᵃ

Kwon et al. [28], Marzoni et al. [21], and Lee et al. [20]. As mentioned previously, increasing the GSP may be helpful for improving the nutritious value of meat, which positively correlated to be improved FCR and increased GH.

Fatty acids composition of treated Muscovy duck fat

The data of FAs composition of extracted fat from minced Muscovy duck' meats are shown in table 10. Twelve fatty acids (6 USFA and 6 SFA) have been identified by GLC. Clearly, the percentages of USFA content of duck meat were 68.83, 65.65 and 65.77%, while these figures for SFA in duck meat were 30.70, 33.33 and 33.51% for CD, DG10 and DG20, respectively. Indeed, in all ducks' meat palmitic acid was the predominant SFA. In addition, the value of palmitic acid decreased with feeding ducks on GSP (72.81% of total SFA in DG20 compared to 74.90% of total SFA in CD meat). Similar trend have been observed for stearic acid. On the contrary, the oleic acid was the major USFA in all duck meat that ranged from 40.50 – 41.83%. Furthermore, oleic acid recorded the highest USFA in DG10 to be 63.08% followed by DG20 as 61.58% of total USFA when compared to 60.77% in CD. Similarly, linolenic acid and gadoic acid increased in ducks fed on GSP-supplemented diets. Undoubtedly, the possibility of using GSP as a source of dietary components in duck's diet could be a principle of guava waste valorization and to finding untraditional sources for duck nutrition. Clearly in the present study, feeding ducks with diet incorporated GSP decreased the most important SFA and increased the most important USFA. Similarly, Muhlisin et al. [36] confirmed that Korean duck had more ω6 fatty acids and total polyunsaturated fatty acids than commercial meat-type ducks fed the same experimental diets. As reported by Khalifa et al. [45] GS contains high USFA content and incorporating it in prepared diet resulted in that the profile of dietary fats was reflected in the fatty acid composition, which was confirmed previously [46]. However, duck meat contains high USFAs, especially oleic and linoleic acids [47]. It is well known that the dietary intake of USFAs is effective in lowering blood lipids levels that could be improved in produced meat by feeding ducks on GSP. The consumption of Muscovy meat enriched with more USFA will represent a better contribution to the human diet and is more profitable, a result observed according to Kwon et al. [28]. As previously presented, 10 and 20% of GSP incorporated into Muscovy duck's diet will be a good starting point to valorize valuable food processing wastes in formulating poultry's diets.

Conclusions

Evidently, incorporation of GSP to ducks diets as new feeding formulas enhanced the FCR, GH and RCC significantly. The EAA and NEAA of GSP-diet fed duck meat were increased by increasing GSP content, even limiting AA compensated by GSP-diet. The FAs profile indicated 8.57 and 9.15% increases in DG5 and DG20 ducks. Inclusion of certain percentage of GSP in duck's diets not only considered an economic feasible approach to reduce the costs of raising this bird, but it also conserved the physical, chemical and nutritional characteristics of such bird meats. Increasing the GSP level in Muscovy duck diet may be increased in a further study.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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