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PRODUCTIVE PERFORMANCE OF ROSS-308 BROILERS FED WITH NUTRITIONALLY AND COST-EFFECTIVE OPTIMIZED DIETS

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Abstract

The goal of the study was to use a linear programming algorithm in trying out to optimize the standard starter, grower and finisher diets of chicken broilers in a familial type microfarm, using the locally available feedstuffs and replacing partially the concentrated protein and energy raw matters (soy meal and vegetable oil) by full-fat soy. The objective function was set to minimize mix production costs, under several restraints related to nutritional value and inclusion proportions of certain raw matters in diets. ROSS 308 broilers have been used as biological material, 750 individuals being allotted randomly in three groups, one of it being considered control, fed with conventional mixed feed (CG), while the other two contained soy meal as main protein concentrate (OG 1 SM group) while the third one contained full-fat soy in diet composition (OG 2 FFS), as well.Feed formulation optimizing led to lower production costs and, subsequently to better production and economic performances (live weight at slaughter improved by 3.29% in full-fat soy group and by 1.52% in soy meal optimized group; FCR better with 0.69-2.14% vs. control; 2.17% to 7.27% improved profits in experimental treatments). As follow-up, it is planned to test the optimized variants on more individuals, to achieve more consistent data and to use a more elaborate data processing methods, such as ANOVA post-hoc testing and regression, in order to estimate the repeatability of such findings in similar future optimizing scenarios.

Key words: broiler nutrition, optimization, cost-effective, feed conversion ratio, revenue

INTRODUCTION

It is essential that poultry farmers provide a perfectly balanced feeding at the lowest possible costs, avoiding meanwhile to affect the feed quality and, subsequently, the fowl productive performances and the economics of the farm itself, knowing that feeding occupies circa 60-65% of the overall production expenses in chicken broilers production (Wilkinson, 2011).

Feed formulation using optimization is one of the ways used to ensure the above mentioned conditions. However, this requires in deep knowledge of many nutritional parameters related to the animal needs and to the feed composition, as well, which could negatively affect poultry flock performance when are not appropriately provided or monitored

(Olugbengaetal., 2015).

Nutritionists should perform a multifactorial analysis of certain critical parameters when formulating broilers diets, such as:availability of certain raw feedstuffs and their market prices (Alqaisi et al., 2017); restrictions related to the inclusion of certain feed raw matters (such as animal originating ingredients, forbidden to be used in the own species feeding or in certain production systems) (Beski et al., 2015); chemical proximate composition and the nutritional value of feedstuffs (Latshaw, 2008); digestibility of certain nutrients such as the energy, protein and mineral sources (Roush et al., 2004); special requirements for essential amino-acids and the digestibility for their sources (Vieira et Angel, 2012); energy-protein density of the raw matters and of the targeted mixture; the appropriate sources of dietary fats, with respect to the legally allowed raw matters and to the technological limitations of inclusion (Kamran et al., 2020); the occurrence of certain limitative factors or hazards: too much raw fiber content (Varastegani et Dahlan, 2014),presence of certain digestion inhibitorymolecules (Dousa et al., 2012) or even of toxic or hazardous compounds that should be inactivated prior to inclusion in feed mixture (Abd El-Hack et al., 2018).

Different methods wereused by nutritionists in optimizing monogastric diets, such as: multiple free iteration, algebraic systems, quadratic Pearson method, Simplex algorithm method, Bat algorithm, Two-by-Two matrix, linear programming and so on (BabicetPeric, 2011).

The linear programming using computer assisted applications is the most commonly used method when there is not possible to find solutions for an optimizing goal using successive free iterations, common simple equations and inequities. Therefore, if a challenge in the real world could be accurately represented by the mathematicalequations of a linear programme, then the method will find the best solutions, either in terms of nutritional quality, either in terms of minimum costs or for both restraints. Furthermore, when the linear programing could not provide feasible solutions, other mathematical algorithms could be used as follow-up, such as Quadratic programming, Integer programming, Dynamic programming (Rahman etal., 2010).

Within the context of several digital solutions available for broilers feeding optimization, the main goal of the research was to identify an optimal mix of feedstuffs to produce combined feed (starter, grower and finisher diets), taking into account the proximate composition of ingredients, the subsequent nutritional or participating constraints, in order to reduce cost and to maintain an appropriate level of nutritional quality. Thereafter, the optimized diets had to be tested on broilers, to find out their productive response and to compute the economic efficiency of optimizing.

MATERIAL AND METHOD

Several consecutive stages have been passed in acquiring the goal of the study implemented in a familial microfarm in Iasi county:

- broilers nutritional requirements have been updated in accordance with the nutritional recommendations of the producer (Aviagen, 2020);
- choice of the locally available and valid feedstuffs to be used, observing the technological, nutritional or legally constraints of usage.
- formulation of a linear programming model, setting up restraints related to nutritional needs; to minimal and maximal inclusion proportions in the mix and orientating the objective function to a minimal cost of production, using the Microsoft Excel 2019 Solver Add-in (Olugbenga et al., 2011);
- comparative analysis of the existing diet in the farm with the new optimized version, containing new introduced ingredients, in term of nutritional value and costs.
- manufacturing and small scale testing of the newly optimized diets on chicken broilers, using the existing one as control.

Biological material: 750 ROSS 308 broilers, reared on permanent litter (slaughter at 40 days old) randomly allotted in 3 groups:

- **CG** – 250 broilers fed with the conventional diets existing in the microfarm (table 1);
- **OG 1 SM** – 250 broilers fed with nutritionally and cost-effectively optimizeddiets (main protein concentrate ingredient – Soymeal);
- **OG 2 FFS** – 250 broilers fed with nutritionally and cost-effectively optimized diets (Soymealpartially replaced by Full-Fat Soy).

Table 1

Conventional diets used in the microfarm
(nutritional requirements of broilers, nutritional facts, price)

STARTER DIET	**Kcal EM/kg**	**%CP**	**%M+C**	**%L**	**%CF**	**%Ca**	**% P**	**Cost/kg**
Nutr. Requirements	3000-3050	23	1.08	1.44	4	0.96	0.48	-
Nutr. facts:	3050	22.82	1.08	1.44	4.00	0.96	0.48	1.649ROL
Ingredients:	Corn, Soymeal, Methionine + Cystine, Lyzine, Limestone (calcium carbonate), Monocalciumphosphate, Premix (oligoelements and vitamins), Salt (NaCl)							
GROWER DIET	**Kcal EM/kg**	**%CP**	**%M+C**	**%L**	**%CF**	**%Ca**	**% P**	**Cost/kg**
Nutr. Requirements	3100-3150	21.5	0.99	1.29	4	0.87	0.43	
Nutr. facts:	3100	21.50	0.99	1.29	3.86	0.87	0.43	1.563ROL
Ingredients:	Corn, Soymeal, Methionine + Cystine, Lyzine, Limestone (calcium carbonate), Monocalciumphosphate, Premix (oligoelements and vitamins), Salt (NaCl)							
FINISHER DIET	**Kcal EM/kg**	**%CP**	**%M+C**	**%L**	**%CF**	**%Ca**	**% P**	**Cost/kg**

Nutr. Requirements	3150-3200	19.5	0.9	1.15	4	0.81	0.39	
Nutr. facts:	3152	19.51	0.89	1.15	3.62	0.82	0.39	1.439ROL
Ingredients:	Corn, Soymeal, Oil, Methionine + Cystine, Lyzine, Limestone (calcium carbonate), Monocalciumphosphate, Premix (oligoelements and vitamins), Salt (NaCl)							

The reasoning criteria for conventional diet replacement with the experimental ones effects were measured by the end of each technological phase (starter 1-10 days, grower 11-24 daysand finisher 25-40days + overall series 1-40days):

- live weight: at the brooding moment, at the end of each phase (gravimetric, g/capita);
- total weight gain per phase and overall series (difference between the final and the initial weight – g/capita; average daily gain - g/day);
- feed intake askg total per group and calculated individually (kg/capita);
- feed conversion ratio (kg feed/kg gain).

The data were measured per 100 individuals from each group and were submitted to statistical processing in MsExcel 2019 – Data Analysis Add-in, to obtain the main descriptors (mean, standard error, variation coefficient), while absolute and relative comparisons were calculated between group. By the end of the experiment, a brief economic calculation was run, in order to assess the efficiency of replacing the conventional diet with the optimized ones.

Study limitations – lack of proximate composition analysis for the locally available feedstuffs used in both type diets (existing and optimized); the nutritional values used in optimizing were takenfrom literature tables. Usage of limited individuals in feed testing (250 broilers/group).

RESULTS AND DISCUSSION

Comparison: optimized diets vs. conventional diets

Considering the specific of the three diets already provided in the microfarm, *in the 1st stage* of the experiment we tried to optimize them nutritionally and for cost effectiveness. We did not opt out for animal originating feedstuffs, motivated by biosecurity and cost reasons.

As objective function we choose to minimize the diet cost and a series of restraints have been applied: total proportion of 100% ingredients in the mix, results to vary between minimum and maximum of ROSS 308 nutritional requirements, fixed proportions for some ingredients (salt at 0.3% and oligo-elements – vitamins premix at 1.0%).

Also, in order to avoid aberrant mathematical solutions, such as negative proportions (feasible algebraically but not relevant in reality), positivity constraints have been also programmed for each feedstuff proportion, as well as some maximal inclusion rate restraints for certain feedstuffs, due to technological manufacturing limitations (eg. maximum fat proportion of 5% in the feed).

The diets optimized in the first stage and fed to OG – 1 – SM group broilers are presented in table 2.

Table 2

Diets optimized nutritionally using the same ingredients as the conventional diets and fed to OG – 1 – SM broilers (nutritional requirements of broilers, nutritional facts, price)

STARTER DIET	**Kcal EM/kg**	**%CP**	**%M+C**	**%L**	**%CF**	**%Ca**	**% P**	**Cost/kg**
Nutr. Requirements	3000-3050	23	1.08	1.44	4	0.96	0.48	-
Nutr. facts:	2987	22.91	1.07	1.44	4.03	0.90	0.47	1.591ROL
Ingredients:	Corn 54.00%, Soymeal 38.30%, Oil 3.47%, Methionine + Cystine 0.34%, Lyzine 0.24%, Limestone (calcium carbonate) 2.00%, Monocalcium phosphate 0.35%, Premix (oligoelements and vitamins) 1%, Salt (NaCl) 0.3%							
GROWER DIET	Kcal EM/kg	%CP	%M+C	%L	%CF	%Ca	% P	Cost/kg
Nutr. Requirements	3100-3150	21.5	0.99	1.29	4	0.87	0.43	
Nutr. facts:	3101	21.44	0.99	1.30	3.85	0.86	0.43	1.560ROL
Ingredients:	Corn 56.50%, Soymeal 34.80%, Oil 4.70% Methionine + Cystine 0.30%, Lyzine 0.18%, Limestone (calcium carbonate) 2.00%, Monocalcium phosphate 0.22%, Premix (oligoelements and vitamins) 1%, Salt (NaCl) 0.3%							
FINISHER DIET	Kcal EM/kg	%CP	%M+C	%L	%CF	%Ca	% P	Cost/kg
Nutr. Requirements	3150-3200	19.5	0.9	1.15	4	0.81	0.39	
Nutr. facts:	3150	19.50	0.90	1.15	3.62	0.81	0.39	1.437ROL
Ingredients:	Corn 62.10%, Soymeal 29.56%, Oil 4.53%, Methionine + Cystine 0.26%, Lyzine 0.17%, Limestone (calcium carbonate) 1.98%, Monocalciumphosphate0.10%, Premix (oligoelements and vitamins) 1%, Salt (NaCl) 0.3%							

In comparison with the diets already used in the microfarm, the results of the optimization did not differ quite much in terms of production cost, especially in Grower (-0.2%) and Finisher (-0.1%) diets. However, in the Starter diet, the richest in crude protein, the optimization brought savings of 3.6% for the production cost.

In the 2nd stage, we thought of introducing a new raw matter in optimizing the three diets, using the Full Fat Soy, as partial replacement for the Soymeal (main protein concentrate ingredient) and for the oils (knowing that full fat soy is also rich in energy). The result of optimization is displayed in table 3 and the diets were provided in OG – 2 – FFS group broilers.

As result of partial replacement of soymealby full-fat-soy, as concentrate ingredient both rich in protein and energy, a higher amplitude of production cost reduction could be observed.

In Starter diet, the production cost decreased by 12.17%, while in Grower feed, the production was 5.9% less expensive. In the last diet

(Finisher), the optimizing brought a production cost decrease by 3.3%. However, these apparently good results, in terms of expenses, had to be tested in terms of broiler production performances.

The influence of the diet on the productive response of the broilers is presented in table 4.

Table 3

Diets optimized nutritionally using the same ingredients as the conventional diets and fed to OG – 2 – FFS broilers (nutritional requirements of broilers, nutritional facts, price)

STARTER DIET	**Kcal EM/kg**	**%CP**	**%M+C**	**%L**	**%CF**	**%Ca**	**% P**	**Cost/kg**
Nutr. Requirements	3000-3050	23	1.08	1.44	4	0.96	0.48	-
Nutr. facts:	3000	22.95	1.08	1.44	4.00	0.96	0.48	1.470ROL
Ingredients:	Corn 59.15%, Soymeal 24.19%, Full fat soy 12.18%, Methionine + Cystine 0.36%, Lyzine 0.34%, Limestone (calcium carbonate) 2.23%, Monocalcium phosphate 0.25%, Premix (oligoelements and vitamins) 1%, Salt (NaCl) 0.3%							
GROWER DIET	Kcal EM/kg	%CP	%M+C	%L	%CF	%Ca	% P	Cost/kg
Nutr. Requirements	3100-3150	21.5	0.99	1.29	4	0.87	0.43	
Nutr. facts:	3100	21.50	0.99	1.29	3.95	0.87	0.43	1.476ROL
Ingredients:	Corn 59.19%, Soymeal 22.92%, Full fat soy 12.77%, Oil 1.25%, Methionine + Cystine 0.28%, Lyzine 0.14%, Limestone (calcium carbonate) 2.15%, Premix (oligoelements and vitamins) 1%, Salt (NaCl) 0.3%							
FINISHER DIET	Kcal EM/kg	%CP	%M+C	%L	%CF	%Ca	% P	Cost/kg
Nutr. Requirements	3150-3200	19.5	0.9	1.15	4	0.81	0.39	
Nutr. facts:	3150	19.50	0.90	1.15	3.67	0.81	0.39	1.393ROL
Ingredients:	Corn 63.59%, Soymeal 23.47%, Full fat soy 6.40%, Oil 2.78%, Methionine + Cystine 0.25%, Lyzine 0.18%, Limestone (calcium carbonate) 2.03%, Premix (oligoelements and vitamins) 1%, Salt (NaCl) 0.3%							

Overall series (1-40 days), the best live weight was achieved by the broilers in groupOG 2 FFS, that received feed optimization through full-fat soy introduction and decreasing of production cost and reached 2603.50 kg/capita (+3.29% versus the control group). In OG 1 SM (feed optimized by production cost reduction) the broilers reached 2.56 kg/capita at slaughter (+1.52% compared to control).

In comparison with the day old weight, that was quite similar (41.1-41.2 g/capita), the broilers cumulated weight gains differentiated through the type of consumed feed: 2479.40±2.03g in control group; 2517.70±2.52g in OG 1 SMgroup (+1.54% vs. control); 2562.30±4.31 g in OG 2 FFS group (+3.34% vs. LC). Therefore, the best cumulated weight gain was obtained by the broilers fed with the diet in that soy meal was partially substituted by full-fat soy and also had the lowest production cost.

In terms of average daily gain, the calculated values varied accordingly, reaching 61.99 g/capita/dayin control group, 62.94 g/capita/dayinOG 1 SS group and 64.06 g/capita/day in OG 2 FFS (1.54 to 3.34% versus control) (table 4).

Cumulated feed intake overall the entire series ranged between 4.49 kg/capita (CG) and 4.54 kg (OG 2 FFS), while the broilers in OG 1 SS group, consumed 4.53 kg feed/capita (table 4).

Feed conversion ratio was calculated at 1.81 kg feed/kg gain in CG (not optimized feed), at 1.79 kg feed/kg gain in OG 1 SS (-0.69% versus CG) and at 1.77 kg feed/kg gain in OG 2 FFS (-2.14% vs. control) (table 4).

Table 4

Productive response of ROSS-308 broilers to diet optimizing, overall the experimental series (life span 1-40 days) (n=100 individuals / group)

Productive trait	Statistical descriptors	CG	OG 1 SM	± % vs. CG	OG 2 FFS	± % vs. CG
Weight at slaughter	Mean ($\bar{X}$) (g)	2520.50	2558.90	+1.52	2603.50	+3.29
	Standard error ($\pm s_{\bar{x}}$)	2.04	2.50	-	4.28	-
	Variation coefficient (v %)	0.81	0.98	-	1.64	-
Total weight gain	Mean ($\bar{X}$) (g)	2479.40	2517.70	+1.54	2562.30	+3.34
	Standard error ($\pm s_{\bar{x}}$)	2.03	2.52	-	4.31	-
	Variation coefficient (v %)	0.82	1.00	-	1.68	-
Average daily gain	Mean ($\bar{X}$) (g/capita/day)	61.99	62.94	+1.54	64.06	+3.34
	Standard error ($\pm s_{\bar{x}}$) (g/capita/day)	0.05	0.06	-	0.11	-
	Variation coefficient (v %)	0.82	1.00	-	1.68	-
Cumulated feed intake	Mean ($\bar{X}$) (kg feed)	4.49	4.53	+0.98	4.54	+1.32
	Standard error ($\pm s_{\bar{x}}$) (kg feed)	0.01	0.01	-	0.01	-
	Variation coefficient (v %)	1.05	2.27	-	2.06	-
Feed conversion ratio	Mean ($\bar{X}$) (kg feed/kg gain)	1.81	1.79	-0.69	1.77	-2.14
	Standard error ($\pm s_{\bar{x}}$) (kg feed/kg gain)	0.01	0.01	-	0.01	-
	Variation coefficient (v %)	1.49	2.57	-	1.78	-

Considering a livability rate of 98.3% in all groups and extrapolating the experimental findings to a computation for 10000 broilers/group, it was found that introducing full fat-soy as partial replacer of soy meal, the feeding expenses per series decreased by 3.4-3.9%, comparing to the other types of diet.

Also, when the weight gain was introduced in computation, the results were better in OG 2 FFS group (+1.7% vs. OG 1 SM group; +3.3% vs. control group).

In terms of profit, the optimized versions generated 7.27% higher revenues (OG 2 FSS group) or 2.17 better results (OG 1 SM group).

CONCLUSIONS

Linear optimizing of the broiler experimental diets, in order to minimize production costs led to better production and economic performances (live weight at slaughter improved by 3.29% in full-fat soy group and by 1.52% in soy meal optimized group; FCR better with 0.69-2.14% vs. control; 2.17% to 7.27% improved profits in experimental treatments).

Therefore, it is recommended to introduce the full-fat soy in all three phases of feeding, assisted by a mix optimizing linear algorithm oriented toward cost minimization as objective function, in order to achieve better gains, lower feed conversion and higher revenue.

Our study, although presents the real results of the optimistic scenario of feed optimizing through the partial substitution of soy meal and vegetable oil by the full fat soy, has some limitations that should be overcome in the research follow-ups by:usage of more subjects in groups; run of analytical laboratory investigations related to feedstuffs proximate composition; usage of more in deep statistical apparatus, that could estimate certain probabilities of findings repeatability in each scenario.

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