USE OF ANALYTICAL HIERARCHY PROCESS BASED ON PRODUCTION PERFORMANCE /COST/ENVIRONMENTAL IMPACT, IN EVALUATING THE EFFICIENCY OF COMPOUND FEEDS FORMULATIONS FOR LAYING HENS

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Abstract

The efficiency of diet formulations that include food industry by-products (rapeseed meal, grape seeds meal, buckthorn meal, pumpkin meal and flax meal) was assessed based on the results of a feeding trial on laying hens (160 TETRA SL layers, 56 weeks) using the Analytical Hierarchy Process (AHP). The methodology involves pair comparisons made by a group of evaluators, which express the relative importance of the criteria and diet formulations that are considered. AHP users first break down the decision problem into a hierarchy of sub-problems that are easier to understand and which can be analysed independently. Three types of criteria were established on the basis of which each evaluator made the hierarchy: (c1) technical (laying percentage and average egg weight); (c2) economic (cost and feed conversion ratio); (c3) ecologic (physical-chemical and microbiologic indicators with ecologic relevance). The assessed compound feeds formulations had the same basal composition (17.44% crude protein and 11.72 MJ/kg feed metabolisable energy) but differed by the added by-products: E1 (9,5 % rapeseed meal + 3 % grape seeds meal); E2 (8,73 % flax meal + 3% buckthorn meal); E3 (9 % pumpkin meal). Based on the production performance, costs and environmental impact, formulation E1 (with rapeseed meal and grape seeds meal) performed best under these particular experimental conditions.

Key words: AHP methodology; criteria; laying hens; compound feeds formulations; by-products

INTRODUCTION

Sustainable agriculture, environmental friendly agricultural practices and responsible management of natural resources are ideas that refer to ecological, technological and socioeconomic dimensions of the broader concept of sustainable development [4; 8]. These concepts point out the multifunctional nature of agriculture but little information, however, is available from multicriteria or systemic perspectives that reflect the multifunctional role of agriculture and the demands of society [6]. Such multifunctional problem is the evaluation of the benefits of using food industry vegetable by-products in poultry feeding. This kind of by-products accounts for over 50% of the “residues” produced in some countries, 60% of them being organic matter. This is an economic social and an environmental problem. Because of their low cost, the by-products that have proper feeding properties can be used as low-cost ingredients in animal diets, as long as they sustain animal health, animal products and the environment quality. One of the methods that can be used to evaluate the efficiency of the dietary formulations for farm animals which include such by-products, is the analytical hierarchy process (AHP). Braunschweig [2] showed that AHP is described by Saaty and Vargas [10] as a multiobjective, multicriteria decision-making approach that employs a pair wise comparison procedure to arrive at a scale of preferences among a set of alternatives. To

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apply this approach, it is necessary to break down a complex, unstructured problem into its component parts, and arrange these parts, or variables, into a hierarchic order. AHP, which was initially developed by Saaty [9], has already been applied to a wide range of complex decision problems [2]. The analytical hierarchy process (AHP) is most useful when the teams are working on complex problems which involve human perceptions and judgements whose resolutions may have long-term consequences [3]. This method has been rather little used in animal production. Thus, a basic AHP model was used to evaluate the efficiency of a set of four smell management strategies in pig farms [5]. Some researchers [7] used the analytical hierarchy process (AHP) to take decisions regarding the annual animal health programs, by assigning priorities to the problems of interest for the goat breeders. Other researcher [1] used the method to hierarchize feeding solutions for layers aiming to decrease the egg cholesterol while protecting the environment.

Purpose of the paper: Use of analytical hierarchy process based on production performance /cost/environmental impact, in evaluating the efficiency of compound feeds which include vegetable by-products for laying hens

MATERIAL AND METHOD

The efficiency of diet formulations that include food industry by-products (rapeseed meal, grape seeds meal, buckthorn meal, pumpkin meal and flax meal) was assessed based on the results of a feeding trial on laying hens (160 TETRA SL layers, 56 weeks). The experiment was conducted for 5 weeks on five groups (C, E1, E2, E3 and E4) of layers. The birds were housed in special three tiers cages (2 hens per cage) which allow the daily recording of the ingesta and excreta. The microclimate conditions in experimental hall were 19.27±1.63^{0}C (temperature) and 65±6.38 % (humidity). The light regimes was adequate to the exploitation age of the layers (8 h darkness, 16 h light). Results obtained in the course of this experiment are shown in Table 1.

Table 1 Production parameters and the indicators of ecologic relevance

Item	Control group	Experiment al group E1	Experiment al group E2	Experiment al group E3	Experiment al group E4
Feed conversion ratio, kg CF/ kg egg	2.08	2.06	2.19	2.07	2.12
Cost/kg compound feed, lei	1.01	1.28	2.18	1.94	1.03
Average egg weight, g	64.95	64.83	63.68	63.01	63.01
Laying percentage, %	88.3	90.56	89.26	86.63	89.69
Concentrations in dry manure					
Cadmium, mg/kg	0.56	0.52	0.56	0.55	0.48
Arsenic, mg/kg	0.28	0.21	0.53*	0.22	0.81*
Lead, mg/kg	0.79	0.74	0.85	0.90	0.71
Nickel, mg/kg	8.1	6.7	7.34	7.59	10.16
E. coli, nr./cm^3	13,5x109	181x10^9	56.8x10^9 *	117x10^9 *	125x10^9 *
Sallmonela	absent	absent	absent	absent	absent

* value exceeded

The basal diet formulation was similar for all 6 groups, the difference between the experimental groups being given by the proportion of vegetable by-products (Table 2). The dietary premix was a conventional one, currently used for this category and age of production.

The following bioproductive parameters were monitored throughout the experimental period: average daily feed intake, feed conversion ratio, laying percentage and egg weight. On weeks 3 and 5 of experiment, 18 eggs/group were collected to determine egg quality. Also on weeks 3 and 5 of experiment, droppings samples were collected daily from each cage and 6 average samples per group were formed in the end of the experiment. Part of these samples were analysed immediately microbiologically and part of them were dried (65 ^{0} C) to determine the heavy metals. A panel of evaluators/experts in the evaluated field or in related fields was established in order to hierarchize the tested feeding solutions. The experts expressed their opinions on the basis of the proposed evidences (experimental results, Table 1), own experience and knowledge, to evaluate the advantages and disadvantages of four proposed diet formulations (Table 2). The panel consists of a group of 3 experts, relevant for the proposed objective.

Table 2 Description of the used diet formulations*

Alternatives (diet)	General description	Main advantages	Main disadvantages
Alt RT1 (E1)	The diet that amends the basal diet of the control group with rapeseeds meal and grape meal	- lowest feed conversion ratio; - the highest laying percentage; - average egg weight very close to the highest weight; - the cost of the formulation is the second top to bottom - the indicators relevant to the environmental impact are lower compared to the control	- the microbiologic indicator Escherichia coli increased most compared to the control;
Alt RT2 (E2)	The diet that amends the basal diet of the control group with flax meal and buckthorn meal	- average egg weight is the second top to bottom - the ecologically physical and chemical indicators relevant to the environmental impact are rather similar to the control group - the microbiologic indicator Escherichia coli increased least compared to the control;	- highest feed conversion ratio - the formulation is more expensive than the control formulation and than the four new formulations - laying percentage is second lowest
Alt RT3 (E3)	The diet that amends the basal diet of the control group with pumpkin meal	- feed conversion ratio closest to the lowest - the ecologically physical and chemical indicators relevant to the environmental impact are rather similar to the control group - expensive formulation, second most expensive of the new formulations	- lowest laying percentage of the new 4 formulations - average egg weight lowest of the new 4 formulations - the microbiologic indicator Escherichia coli higher than the control;
Alt RT4 (E4)	The diet that amends the basal diet of the control group with full fat mixt	- best price of cost, very close to the control group - laying percentage second highest - the ecologically physical and chemical indicators relevant to the environmental impact are rather similar to the control group	- lowest average egg weight (like E3) - feed conversion ratio second top to bottom - the microbiologic indicator Escherichia coli higher than the control;

*RT comes from the formulation, the alternatives actually being the 4 experimental formulations E1, E2, E3 and E4.

The main objective to be fulfilled is formulated in the hierarchy shown in Table 3: “developing a feeding solution based on production/egg quality/cost/environmental impact, which can be recommended for the farmers”. The best formulation must be selected analysing the values and trends of the indicators that are relevant for the proposed objective.

Table 3 Hierarchic levels designed for the evaluation and classification of the 4 experimental formulations

Objective level	Objective "determine a feeding solution, based on production/egg quality/ cost/ environmental impact, which can be recommended to the farmers"											
Criteria level	c1=technical criterion				c2= economic criterion				c3= ecologic criterion			
Level of the alternatives	Alt RT1	Alt RT2	Alt RT3	Alt RT4	Alt RT1	Alt RT2	Alt RT3	Alt RT4	Alt RT1	Alt RT2	Alt RT3	Alt RT4

Three large criteria were selected from the Table 1 by the panel to be used for the evaluation; C1 technical criterion: laying percentage and average egg weight; C2 economic criterion: feed price and feed conversion ratio; C3 ecologic criterion: the physical-chemical and microbiological indicators of ecologic relevance.

RESULTS AND DISCUSSION

Each evaluator made his own hierarchy according to the three types of criteria C1÷C3 agreed by the panel. According to the AHP methodology, this hierarchy is done by writing a 3x3 type A matrix [1] because there are n=3 types of criteria to be written in the lines and columns of the matrix. Any entry on line "j" and column "k" is marked as pjk, where j= 1÷n and n=3 and k=1÷n and n=3. Following are the matrices A 3x3, done by the three evaluators, showing the weight of the criteria:

c1	1	1/2	5									
c2	2	1	6									
c3	1/5	1/6	1									
	A			n	3	wi	∑i=1,3(AW)i/wi	λmax	CI=(λmax-n)/(n-1)	CR=CI/RI	RI	Consistenta
Eval I-(C1C2C3)-A(3x3)	c1	c2	c3	1/3								
c1	1.000	0.500	5.000	2.500	1.357	***0.342***	3.029					
c2	2.000	1.000	6.000	12.000	2.289	***0.577***	3.029					
c3	0.200	0.167	1.000	0.033	0.322	***0.081***	3.029					
					3.968		**9.087**	**3.029**	**0.015**	**0.025**	**0.58**	**1**

Eval II-(C1C2C3)-A(3x3)	c1	c2	c3									
c1	1	2	5									
c2	1/2	1	4									
c3	1/5	1/4	1									
	A			n	3	wi	∑i=1,3(AW)i/wi	λmax	CI=(λmax-n)/(n-1)	CR=CI/RI	RI	Consistenta
Eval II-(C1C2C3)-A(3x3)	c1	c2	c3	1/3								
c1	1.000	2.000	5.000	10.000	2.154	***0.570***	3.025					
c2	0.500	1.000	4.000	2.000	1.260	***0.333***	3.025					
c3	0.200	0.250	1.000	0.050	0.368	***0.097***	3.025					
					3.783		**9.074**	**3.025**	**0.012**	**0.021**	**0.58**	**1**

Eval III-(C1C2C3)-A(3x3	c1	c2	c3									
c1	1	1	4									
c2	1	1	4									
c3	1/4	1/4	1									
	A			n	3	wi	∑i=1,3(AW)i/wi	λmax	CI=(λmax-n)/(n-1)	CR=CI/RI	RI	Consistenta
Eval III-(C1C2C3)-A(3x3)	c1	c2	c3	1/3								
c1	1.000	1.000	4.000	4.000	1.587	***0.444***	3.000					
c2	1.000	1.000	4.000	4.000	1.587	***0.444***	3.000					
c3	0.250	0.250	1.000	0.063	0.397	***0.111***	3.000					
					3.572		**9.000**	**3.000**	**0.000**	**0.000**	**0.58**	**1**

From these matrices it results that the weight of the criteria (w_i) is the following: Evaluator 1: C1=0.342; C2=0.577; C3=0.081; Evaluator 2: C1=0.570; C2=0.333; C3=0.097; Evaluator 3: C1=0.444; C2=0.444; C3=0.111.

Following, each evaluator hierarchized the four experimental diet formulations (alternative) AltRT1÷AltRT4, in connection with each criterion. According to the AHP methodology, this hierarchy is done by writing a 4x4 B matrix for each criterion C1, C2 and C3 because there are m=4 experimental alternatives to be written in the lines and columns of the matrix. Any entry on line "j" and column "k" is marked as p_{jk}, where j= 1÷m and m=4 and k=1÷m and m=4; Each evaluator filled in these matrices, called pair comparison matrices, using the Saaty scale [1].

Following is an example of 4x4 B matrix that evaluates the alternatives, as done by evaluator 1.

Eval_I-(C1)-A(4x4)	Alt RT1	Alt RT2	Alt RT3	Alt RT4
AltRT1	1	3	5	3
AltRT2	1/3	1	3	1
AltRT3	1/5	1/3	1	1/3
AltRT4	1/3	1	3	1

	A				n	4		wi	∑i=1¸4(AW)i/wi	λmax	CI=(λ max-n)/(n-1)	CR=CI/RI	RI	Consistenta
Eval I_C1)-A(4x4)	Alt RT1	Alt RT2	Alt RT3	Alt RT4		1/4								
AltRT1	1.000	3.000	5.000	3.000		45.000	2.590	*0.520*	4.062					
AltRT2	0.333	1.000	3.000	1.000		1.000	1.000	*0.201*	4.022					
AltRT3	0.200	0.333	1.000	0.333		0.022	0.386	*0.078*	4.068					
AltRT4	0.333	1.000	3.000	1.000		1.000	1.000	*0.201*	4.022					
							4.976		***16.174***	***4.04338***	***0.01446***	***0.01607***	***0.90000***	***1.00000***

Eval I-(C2)-A(4x4)	Alt RT1	Alt RT2	Alt RT3	Alt RT4
AltRT1	1	6	5	1/2
AltRT2	1/6	1	1/2	1/7
AltRT3	1/5	2	1	1/6
AltRT4	2	7	6	1

	A				n	4		wi	∑i=1¸4(AW)i/wi	λmax	CI=(λ max-n)/(n-1)	CR=CI/RI	RI	Consistenta
Eval I_C2)-A(4x4)	Alt RT1	Alt RT2	Alt RT3	Alt RT4		1/4								
AltRT1	1.000	6.000	5.000	0.500		15.000	1.968	*0.337*	4.067					
AltRT2	0.167	1.000	0.500	0.143		0.012	0.330	*0.057*	4.071					
AltRT3	0.200	2.000	1.000	0.167		0.067	0.508	*0.087*	4.068					
AltRT4	2.000	7.000	6.000	1.000		84.000	3.027	*0.519*	4.071					
							5.834		***16.277***	***4.06933***	***0.02311***	***0.02568***	***0.90000***	***1.00000***

Eval I-(C3)-A(4x4)	Alt RT1	Alt RT2	Alt RT3	Alt RT4
AltRT1	1	1/5	1/4	1/4
AltRT2	5	1	2	2
AltRT3	4	1/2	1	1
AltRT4	4	1/2	1	1

	A				n	4		wi	∑i=1¸4(AW)i/wi	λmax	CI=(λ max-n)/(n-1)	CR=CI/RI	RI	Consistenta
Eval I_C3)-A(4x4)	Alt RT1	Alt RT2	Alt RT3	Alt RT4		1/4								
AltRT1	1.000	0.200	0.250	0.250		0.013	0.334	*0.069*	4.043					
AltRT2	5.000	1.000	2.000	2.000		20.000	2.115	*0.438*	4.040					
AltRT3	4.000	0.500	1.000	1.000		2.000	1.189	*0.246*	4.014					
AltRT4	4.000	0.500	1.000	1.000		2.000	1.189	*0.246*	4.014					
							4.828		***16.111***	***4.02769***	***0.00923***	***0.01026***	***0.90000***	***1.00000***

	c1	c2	c3	
	0.342	**0.577**	**0.081**	
AltRT1	0.520	0.337	0.069	**0.378**
AltRT2	0.201	0.057	0.438	**0.137**
AltRT3	0.078	0.087	0.246	**0.097**
AltRT4	0.201	0.519	0.246	**0.388**

The table below shows the evaluations of the panel specialists using the AHP method.

Table 4 Results of the evaluation done by the three evaluators and resulting hierarchy

Ev.1	c1	c2	c3		Ev.2	c1	c2	c3		Ev. 3	c1	c2	c3		Average	Hierarchy
	0.342	**0.577**	**0.081**			**0.570**	**0.330**	**0.097**			**0.444**	**0.444**	**0.111**			
RE 1	0.520	0.337	0.069	**0.378**	AltRT1	0.532	0.328	0.082	**0.419**	AltRT1	0.433	0.336	0.484	**0.395**	**0.397**	**I**
RE 2	0.201	0.057	0.438	**0.137**	AltRT2	0.161	0.053	0.449	**0.152**	AltRT2	0.239	0.051	0.148	**0.145**	**0.145**	**III**
RE 3	0.078	0.087	0.246	**0.097**	AltRT3	0.064	0.110	0.235	**0.095**	AltRT3	0.088	0.096	0.318	**0.117**	**0.103**	**IV**
RE 4	0.201	0.519	0.246	**0.388**	AltRT4	0.244	0.510	0.235	**0.330**	AltRT4	0.239	0.517	0.050	**0.341**	**0.343**	**II**

Where: ev= evaluator; c= criterion; RE= experimental diet formulation

CONCLUSIONS

- The use of AHP method allowed making in good time group decisions regarding the efficiency of diet formulations for layers using the tested by-products, each evaluator showing his own ranking of the agreed criteria.
- Within the paradigm of the sustainable development of the agriculture, the use of AHP method is an analytical instrument to solve practically the complex problems facing the decision-making process.

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