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Modelling production functions and economic weights in intensive meat production of guinea pigs

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ABSTRACT: A profit function for a typical commercial farm of intensive guinea pig production was designed. The simulated farm contained 86 cages with a ratio of 7:1 females:males, with continuous mating. Kits were weaned at 15 d of age and slaughtered for meat production at 90 d of age. The absolute (EW) and relative economic weights of the main traits were calculated. The highest EW were kits produced per kindling ($US 25), kits weaned per kindling ($US 22), kits born alive per kindling ($US 20), and number of kindlings per female and year ($US 12). Profit, returns and costs per female and year were $US 15, 68 and 53, respectively. Returns came from production of young guinea pigs and discarded reproductive adults for meat production, 90% and 10% of the total returns. The highest costs were feeding and labor, 44% and 23% of the total cost. The EW and profit did not substantially change when simulating variations of ±20% in the prices of kg of fattening feed and kg of live weight of guinea pig, showing their robustness to future variations in market prices or to variations in prices between countries. The results obtained highlight the importance of the feeding costs in the guinea pig meat production.

Keywords: Cavia porcellus, economic weights, guinea pig, meat production, profit function.

INTRODUCTION

The guinea pig (Cavia porcellus) provides a significant amount of protein for the diets of small farmers in a large part of South America and contributes reducing malnutrition (Chupin, 1995). Studies in guinea pig for meat production have focused on carcass composition, meat quality, nutrition, genetic selection and social impact, but none of them has evaluated the economic production functions in which costs and returns are clearly established and benefits from improving different characters are assessed. To our knowledge, no studies about economic weights in guinea pig production have been developed. We propose in this study to construct, for the first time, a profit function for guinea pig industrial meat production, and we give a first approximation to the economic weights.

MATERIALS AND METHODS

Production system

We simulate a typical industrial farm of 86 males and 7 females per male, i.e., 602 females. The farm has one area, managed by one person. Guinea pigs are allocated in 352 cages, 86 for reproductive adults and lactating kits and 266 for kits after weaning. The reproduction system is natural and continuous mating.

Reproductive adults are fed with forage and a commercial reproductive feed. Kindling takes place at 68 d after mating, and females present new estrous 3.5 hours post-partum or 16.4 d after if no pregnancy is reached after the first estrous (Chupin, 1995). Kits are both lactating and consuming forage and commercial preweaning feed from birth to weaning at 15 d of age. After weaning, kits are allocated by sex in groups, of up to 25 kits, until 35 d of age, and are fed with forage and a commercial feed. After the growth period, kits are fed with a commercial fattening feed. The 28% of the females and 4% of the males are kept for replacement. At sexual maturity, 10% of replacement is sold to other farms, and a similar percentage is bought from other farms to avoid inbreeding. The rest of the animals are used for meat production. Replacement animals and kits for meat are kept in cages of 15 males or 20 females during the fattening period. Both replacement and production animals are reared in the same conditions, with forage and commercial fattening feed. After 55 d of fattening (90 d of age) kits for meat production are slaughtered. Replacement females and males start their reproductive cycle with first mating after 35 and 85 d in fattening, respectively (70 and 120 d of age).

Profit function

Profit (P), in $US per reproductive female and year, was calculated with the function:

P = Returns – Costs = [ProdR + DisFR + DisMR] - [PreFeC + GFeC + FatFeProdC + ReFFatFeC + ReMFatFeC + RepFFeC + RepMFeC + OC]

Where, in alphabetical order

DisFR and DisMR discarded females and males returns sold for meat at the end of their reproductive life;

FatFeProdC fattening feeding costs of kits;

PreFeC and GFeC preweaning and growth feeding costs of kits;

OC other costs

ProdR production returns from selling kits for meat;

ReFFatFeC replacement females fattening feeding costs;

ReMFatFeC replacement males fattening feeding costs;

RepFFeC reproductive females feeding costs;

RepMFeC reproductive males feeding costs;

The different returns and costs were calculated as:

ProdR=BAK x KY x PreSu x GSu x (1 - RaSeFRe - RaSeMRe) x SuFatProd x (Bw + WGaPre x TPRE + WGaG x TG + WGaFatProd x TFatProd) x PrSProdSl

DisFR= BAK x KY x PreSu x GSu x (1 - RaSeFRe - RaSeMRe) x SuFatProd x RaSeFRe x WDisRepAd x PrSDisSl

DisMR = BAK x KY x PreSu x GSu x (1 - RaSeFRe - RaSeMRe) x SuFatProd x RaSeMRe x WDisRepAd x PrSDisSl

PreFeC = BAK x KY x [(1 + PreSu)/2] x TPRE x (FeIntPre x PrLFe + ForIntPre x PrFor)

GFeC = BAK x KY x PreSu x [(1 + GSu)/2] x TG x (FeIntG x PrGFe + ForIntG x PrFor)

FatFeProdC = BAK x KY x PreSu x GSu x (1 - RaSeFRe - RaSeMRe) x [(1 + SuFatProd)/2] x TFatProd x (FeIntFatProd x PrFatFe + ForIntFat x PrFor)

ReFFatFeC = BAK x KY x PreSu x GSu x RaSeFRe x FatSuReF x TFatFRe x (FeIntFatReF x PrFatFe + ForIntFatReF x PrFor)

ReMFatFeC = BAK x KY x PreSu x GSu x RaSeMRe x FatSuReM x TFatMRe x (FeIntFatReM x PrFatFe + ForIntFatReM x PrFor)

RepFFeC = 365 x (FeIntRepF x PrAdFe + ForIntRepAd x PrFor)

RepMFeC = 365 x (FeIntRepM x PrAdFe + ForIntRepAd x PrFor) x RaMF

OC = LabC + HC + UtC + AmC + InC + OpC

Where, in alphabetical order,

AmC depreciation costs;

BAK born alive per kindling;

FatSuProd fattening survival for production animals;

FatSuReF fattening survival for replacement females;

FatSuReM fattening survival for replacement males;

FeIntFatReF average daily feed intake in fattening for replacement females;

FeIntFatReM average daily feed intake in fattening for replacement males;

FeIntFatProd average daily feed intake in fattening in kits for meat production;

FeIntG average daily feed intake in growth; FeIntPre average daily feed intake in preweaning;

FeIntRepF average daily feed intake of the reproductive females;

FeIntRepM average daily feed intake of the reproductive males;

ForIntFatReF forage intake in fattening for the replacement females;

ForIntFatReM forage intake in fattening for replacement males;

ForIntFatProd forage intake in fattening for production;

ForIntG forage intake in growth; ForIntPre forage intake in preweaning;

ForIntRepAd forage intake of reproductive adults; GSu growth survival;

HC health costs;

InC interest costs;

KY kindlings per year;

LabC labor costs;

OpC opportunity cost;

PrAdFe price of reproductive feed;

PreSu preweaning survival;

PrFatFe price of fattening feed;

PrFor price of forage;

PrGFe price of growth feed;

PrLFe price of preweaning feed;

PrSDisSl price of sale of discarded at slaughter;

PrSProdSl price of sale of production at slaughter;

RaMF ratio of males:females;

RaSeFRe ratio of selection of females for replacement;

RaSeMRe ratio of selection of males for replacement;

TFatReF time in fattening of replacement females;

TFatReM time in fattening for replacement males;

TFatProd time in fattening of production; TG time of kits in growth;

TPre time of kits in preweaning; UtC utilities costs;

WDisRepAd weight of the discarded reproductive adults;

WGaFatProd average daily gain in fattening of production;

WGaG average daily gain in growth;

WGaPre average daily gain in preweaning.

The mean values and prices assumed in the profit function are shown in Table 1.

Economic variables of the profit function

Labor cost of the producer was established as 1.5 times the national minimum agricultural salary in Peru (DS. Nº 007-2012-TR), since Peru is a typical country of guinea pig production. A robustness analysis was developed to take into account salary variations among countries. The labor cost was increased 35% to consider the extra labor costs due to the non-working d and holidays. The utilities costs include water, electricity, communications, maintenance and others. The initial inversion costs estimated were $US 24,845 for land purchase, $US 58,198 for building and equipment of the farm, and $US 7,853 for the initial acquisition of animals. The building and equipment are considered to have a lifespan of 30 year, but 15 for cages. The depreciation per year was the total capital invested in buildings and equipment divided by 30 year. The capital was assumed to have a nominal interest of 24% for building and purchasing of the equipment and initial animals, and 15% for land purchase. Both credits are assumed to be 10-year credit, and interest per year was obtained by dividing the total interest per 30 year. The opportunity cost was calculated as the return/payment that would be obtained by investing the money required for land purchase, building and equipment purchase, and initial animal purchase in a fixed-term deposit at 2.75%. The depreciation, interest and opportunity costs are calculated in constant $US by contemplating a rate of 2.71% of depreciation of the capital. These figures can be easily changed to accommodate other perspectives. The total of kg of live weight produced was calculated as the sum of the kg of live weight obtained with kits for meat production. Returns, costs and profit were expressed per reproductive female and year, per kg of live weight, and also as percentage respect to the total returns and costs.

Economic weights

The absolute economic weight EW_i of a trait x_i was calculated as:

$$EW_i = \partial P/\partial x_i$$

thus, the partial derivate of the profit function with respect to the trait x_i. Traits considered were BAK, KY, ED, NWK, NPK, BW, WGaPre, WGaG, WGaFatProd, FeIntPre, FeIntG, FeIntFatProd, ForIntPre, ForIntG, ForIntFatProd, PreSu, GSu, and FatSuProd. The EW expresses the change in profitability when increasing trait x_i in one unit, without changes in other traits. Relative economic weights (REW) for each trait were obtained dividing the EW by the highest EW.

Sensitivity analysis for economic sustainability

Sensitive analyses were performed to study the variations in profit, returns and costs in case of variation of salary (minimum and twice the agricultural salary), price of fattening feed (-20% and +20% the current price considered) and price paid per kg of guinea pig at slaughter (-20% and +20% the current price considered). Absolute and relative economic weights when varying these prices were also calculated.

RESULTS

Economic weights

The absolute and relative economic weights of the different traits are shown in Table 2. The highest EW were the number of kits produced per kindling, number of kits weaned per kindling and number of born alive per kindling. If production is increased in one kit produced per kindling, profit will be increased in $US 25 per female and year. The EW of preweaning, growth and fattening survival for production animals were low, and the ADG during fattening had a higher EW than birthweight and the ADG during preweaning and growth.

Economic profitability

Returns, costs, profit and the percentage of each item with respect to total returns or total costs are shown in Table 3. Returns per female and year were $US 68. The main income was due to the sale of animals after fattening for meat production, which represented 90% of the total of the returns. The production cost per female and year was $US 53. The highest cost was feeding. The labor cost per female and year represented a 23% of the total cost. The profit per female and year was $US 15.

Sensitivity analysis for economic sustainability

The variations considered in price of fattening feed and price paid per kg of guinea pig changed the values of EW and REW, but did not vary the order of importance of the economic values (Table 4). The profit obtained varied from $US 19 or $US 11. When considering a price of fattening feed 20% lower or higher than the actual price, profits were $US 16 and $US 14, respectively. The decrease or increase of the price paid per kg of guinea pig in 20% led to profits of $US 3 and $US 27, respectively.

DISCUSSION

Economic studies should be accommodated to figures in each country, but the profit function is going to be the same across countries, and only the actual figures used would change. Some of the differences between countries are going to be rather irrelevant, for example in depreciation costs, since they do not suppose an important part of the total cost of production. For other substantial differences in inputs (salaries and food costs), sensitivity analysis permits to accommodate our results to other situations in other countries.

The EW obtained can be used both to improve management and to decide the breeding objectives. The absolute and relative economic weights obtained are within the range of the economic weights obtained in other prolific minority species. In rabbits, Cartuche et al. (2014) also observed high values for born alive per kindling, and similar REW for feed intake, kits survival and ADG. The number of kindlings per female and year, which had also a high value, is related to fertility. If empty days tend to null, the number of kindlings per year could tend to the maximum biological value of 5.37 kindlings per female and year.

Feeding cost was the highest, 44% of the total cost, as happens in other animal productions. In general, the results obtained in returns and production costs agree with results found in other meat productions. The farm profit obtained was not high. However, it should be pointed out that the farmer does not receive only this profit, but also the salary acquired by self-employment and the opportunity cost estimated in the present study. This is a typical situation in agriculture.

The salary was 1.5 times of the national minimum agricultural salary in Peru because the producer is supposed to be a qualified worker with background and experience in guinea pig production management. As salaries can vary between countries, and market prices for feed and meat could significantly vary in a medium-long term, sensitive analyses were performed, showing that profit would be positive when varying labor cost between the minimum and twice the minimum agricultural salary established (Table 5). Thus, the activity would remain profitable in other countries if the salary were within this range of variation. Profit also stayed positive when increasing and decreasing 20% the price of fattening feed and the liveweight price, showing the robustness of the profitability to changes in prices. The variation of profit was higher when varying the price paid per kg of guinea pig than when varying the price of feed. Other studies confirm that the profit is more sensitive to changes in the prices of sale at slaughter than to price of the forage or feed (Chirinos et al., 2008; Espinoza et al., 2008). The economic weights changed after increasing and decreasing the price of fattening feed and the price paid per kg of guinea pig (Table 4), but the order of importance of the economic weights was the same.

ETHICAL STANDARDS

Informed consent was obtained from all participants included in the study. This article does not contain any studies with animals performed by any of the authors.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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Table 1. Mean values, costs and prices assumed for the variables in the profit function of guinea pig meat production.

Variable	Mean	Source
Preweaning survival	0.91	Adapted from Jimenez (2005)
Growth survival	0.97	
Fattening survival for production animals	0.93	
Fattening survival for replacement females	0.95	
Fattening survival for replacement males	0.89	
Number of kits born alive per kindling	3.36	Humberto-Rodriguez et al. (2013)
Number of kindlings per year	4.5	Chupin(1995)
Birthweight (g)	122	Adapted from Instituto de Investigación Agraria (1991)
Average daily gain in preweaning (g/day)	6.1	
Average daily gain in growth and fattening (g/day)	10.9	
Weight of the discarded reproductive adults (g)	1148	
Average daily feed intake in preweaning (g/day)	2.3	Adapted from Ministerio de Agricultura, Ganadería, Acuacultura y Pesca de
Average daily feed intake in growth (g/day)	8.2	Ecuador (2014)
Average daily feed intake in fattening in kits for meat production (g/day)	20.5	
Average daily feed intake of fattening for replacement females (g/day)	17.2	
Average daily feed intake of fattening for replacement males (g/day)	25.4	
Average daily feed intake of reproductive females in preweaning (g/day)	35.0	
Average daily feed intake of reproductive males (g/day)	30.0	

Forage intake in preweaning (g/day)	31.0	
Forage intake in growth (g/day)	110.9	
Forage intake in fattening (g/day)	277.2	
Forage intake in fattening for replacement females (g/day)	232.8	
Forage intake in fattening for replacement males (g/day)	343.7	
Forage intake of reproductive adults (g/day)	225.0	
Price of sale at slaughter for production animals ($US/kg)	6.83	Chancay (2015)
Price of sale at slaughter for discarded animals ($US/kg)	4.35	
Price per kg of preweaning feed ($US/kg)	0.56	Universidad Nacional Agraria La Molina (2015)
Price per kg of growth feed ($US/kg)	0.53	
Price per kg of fattening feed ($US/kg)	0.51	
Price per kg of reproductive feed ($US/kg)	0.54	
Price per kg of forage ($US/kg)	0.03	Espinoza et al. (2008)
Health cost ($US/female and year)	2.62	

Table 2. Absolute (EW) and relative (REW) economic weights of the main traits obtained from a profit function of guinea pig meat production ($US/unit of the trait).

Trait	EW	REW
Number of born alive per kindling	19.68	0.78
Number of kindlings per female and year	12.24	0.48
Empty days	-0.67	-0.03
Number of weaned per kindling	21.80	0.86
Number of produced per kindling	25.24	1.00
Birthweight (g)	0.06	0.00
Average daily gain in preweaning (g/d)	0.88	0.03
Average daily gain in growth (g/d)	1.18	0.05
Average daily gain in fattening(g/d)	3.24	0.13
Average daily feed intake in preweaning (g/d)	-0.10	0.00
Average daily feed intake in growth (g/d)	-0.12	0.00
Average daily feed intake in fattening (g/d)	-0.25	-0.01
Average daily feed intake of reproductive females	-0.20	-0.01
Average daily feed intake of reproductive males (g/d)	-0.03	0.00
Forage intake in preweaning (g/d)	-0.01	0.00
Forage intake in growth (g/d)	-0.01	0.00
Forage intake in fattening (g/d)	-0.02	0.00
Forage intake in reproductive adults (g/d)	-0.01	0.00
Preweaning survival (%)	0.61	0.02
Growth survival (%)	0.58	0.02
Fattening survival in production animals (%)	0.68	0.03

Table 3. Distribution of returns, costs, and profit in guinea pig meat production.

Item	$US per reproductive female	$US per kg live weight	% total
Returns	67.76	7.62	
Production	60.78	6.83	89.70
Discarded reproductive adults	6.98	0.78	10.30
Females	6.12	0.69	9.03
Males	0.86	0.10	1.27
Costs	52.64	5.92	
Feeding	23.25	2.61	44.17
Preweaning	0.40	0.05	0.77
Growth	1.75	0.20	3.33
Fattening for meat production	9.25	1.04	17.57
Replacement	1.25	0.14	2.38
Females	0.86	0.10	1.62
Males	0.40	0.04	0.76
Reproductive adults	10.60	1.19	20.13
Females	9.39	1.06	17.85
Males	1.20	0.14	2.28
Health	2.62	0.29	4.98
Labor	12.30	1.38	23.37
Utilities cost	2.68	0.30	5.08
Water, power, phone, others	1.86	0.21	3.53
Maintenance	0.82	0.09	1.55
Depreciation	3.22	0.36	6.12
Opportunity cost	1.81	0.20	3.44
Interest	6.76	0.76	12.84
Profit	15.11	1.70	

Table 4. Absolute (EW) and relative (REW) economic weights in guinea pig meat production when varying price of fattening feed and price per kg of guinea pig.

	EW				REW			
	Price of fattening		Price per kg of		Price of fattening		Price per kg of guinea	
Trait	-20%	20%	-20%	20%	-20%	20%	-20%	20%
Number of born alive per kindling	20.90	19.27	15.34	24.02	0.82	0.77	0.75	0.80
Numbers of kindlings per female and year	12.50	11.99	9.54	14.95	0.49	0.48	0.47	0.50
Empty days	-0.69	-0.66	-0.52	-0.82	-0.03	-0.03	-0.03	-0.03
Number of weaned per kindling	22.25	21.16	17.01	26.58	0.88	0.85	0.83	0.88
Number of produced per kindling	25.42	25.03	20.38	30.07	1.00	1.00	1.00	1.00
Birthweight (g)	0.06	0.06	0.05	0.07	0.00	0.00	0.00	0.00
Average daily gain in preweaning (g/d)	0.88	0.88	0.71	1.06	0.03	0.04	0.03	0.04
Average daily gain in growth (g/d)	1.18	1.18	0.94	1.41	0.05	0.05	0.05	0.05
Average daily gain in fattening(g/d)	3.24	3.24	2.59	3.89	0.13	0.13	0.13	0.13
Average daily feed intake during preweaning (g/d)	-0.10	-0.10	-0.10	-0.10	0.00	0.00	0.00	0.00
Average daily feed intake during growth (g/d)	-0.12	-0.12	-0.12	-0.12	0.00	0.00	-0.01	0.00
Average daily feed intake during fattening (g/d)	-0.20	-0.30	-0.25	-0.25	-0.01	-0.01	-0.01	-0.01
Average daily feed intake of reproductive females	-0.20	-0.20	-0.20	-0.20	-0.01	-0.01	-0.01	-0.01
Average daily feed intake of reproductive males (g/d)	-0.03	-0.03	-0.03	-0.03	0.00	0.00	0.00	0.00
Forage intake in preweaning (g/d)	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
Forage intake in growth (g/d)	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
Forage intake in fattening (g/d)	-0.02	-0.02	-0.02	-0.02	0.00	0.00	0.00	0.00
Forage intake in reproductive adults (g/d)	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
Preweaning survival (%)	0.62	0.60	0.48	0.74	0.02	0.02	0.02	0.02
Growth survival (%)	0.59	0.57	0.45	0.70	0.02	0.02	0.02	0.02
Fattening survival in production animals (%)	0.69	0.68	0.55	0.81	0.03	0.03	0.03	0.03

Table 5. Returns, costs and profit ($US per reproductive female and year) in guinea pig meat production when varying salary, price of fattening feed and price per kg of guinea pig.

Item	Salary		Price of fattening feed		Price per kg of guinea pig	
	Minimum[a]	Twice minimum[b]	-20%	+20%	-20%	+20%
Returns	67.76	67.76	67.76	67.76	55.60	79.91
Production returns	60.78	60.78	60.78	60.78	48.62	72.93
Discarded	6.98	6.98	6.98	6.98	6.98	6.98
Costs	48.54	56.74	51.49	53.80	52.64	52.64
Feeding	23.25	23.25	22.10	24.41	23.25	23.25
Health	2.62	2.62	2.62	2.62	2.62	2.62
Labor	8.20	16.40	12.30	12.30	12.30	12.30
Utilities cost	2.68	2.68	2.68	2.68	2.68	2.68
Depreciation	3.22	3.22	3.22	3.22	3.22	3.22
Opportunity cost	1.81	1.81	1.81	1.81	1.81	1.81
Interest	6.76	6.76	6.76	6.76	6.76	6.76
Profit	19.21	11.01	16.27	13.96	2.96	27.27

[a] Minimum agricultural salary; [b] Twice the minimum agricultural salary