Economic Evaluation of Amylolytic Enzymes in Finishing Lambs Diet in Mexico

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Abstract: There are no economic evaluations on the use of exogenous amylolytic enzymes in intensive finishing lambs systems in high grain rations. In this document, the profit margins per head were determined for treatments which included enzymes from three experiments. The results indicate that the inclusion of exogenous amylolytic enzymes may result in a very limited range of profit (two experiments) and were not profitable in one experiment. The price of grains will determine whether it is profitable to add enzymes combined with the reduction of grain level in the ration. The profit margin when lamb is processed as barbecued (typical dish) is greater than the sale per kg of live weight. The study adds basic economic information on the use of exogenous amylolytic enzymes in finishing lamb.
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1. Introduction

Most lambs in Mexico are consumed as a typical barbecue in the metropolitan area of Mexico City and populations of central Mexico and it can be estimated that annually around one million of lambs are finished in intensive systems with high grain diets (Mendoza *et al*., 2014). Those grain-based systems started in the early nineties and have been developed; however, the sheep meat demand is not covered by national production and imports cover more than 50% (SAGARPA, 2006-2012).

The great development of new units of intensive sheep production is also explained because sheep are more resistant to acidosis than cattle and are more efficient at converting grain into meat; the price of a kilogram of live weight is higher than that of cattle; and the price of the barbecued lamb (typical dish) is very high relative to the unprocessed meat (Mendoza *et al*., 2014). Despite the years of this activity, there are no published data on production costs; however, several national and transnational companies market commercial concentrates for finishing lambs (Mendoza *et al*., 2007) and this is considered a profitable activity in the opinion of the members of the National Union of Sheep Producers (OUNO, 2008).

Corn and sorghum are the major cereals included in finishing diets of sheep. Although they are highly digestible, the rumen digestion is incomplete and the use of exogenous amylolytic enzymes can improve the utilisation (Gutiérrez *et al*., 2005) particularly from sorghum grain because its starch exhibits greater variability in ruminal digestion (Calderon *et al*., 2011; Duran *et al*., 2004). Mexican researchers have devoted considerable efforts to find ways to incorporate thermostable amylase and glucoamylase in lamb rations to improve the efficiency of feed utilisation of high grain diets, but the profit margin of the incorporation of these technologies has not been evaluated (Rojo *et al*., 2005; Crosby *et al*., 2006; Lee *et al*., 2010; Mota *et al*., 2011; Mendoza *et al*., 2013).

Therefore, this study was conducted to evaluate the profit margin of three experiments with amylolytic enzymes in finishing lambs diets and to explore the profitability when lambs are processed as barbecue or sold at the end of the feedlot period.

2. Material and Methods

Results from three experiments with thermostable amylolytic enzymes produced by ENMEX de Mexico included in finishing lambs ration were selected for the evaluation. The composition of feeds and ration (dry matter), daily gain, intake, initial weight, carcass yield and length of the feedlot evaluation experiment were recorded from all treatments. Experiments selected were from Rojo *et al*. (2005), Lee *et al*. (2010) and Mendoza *et al*. (2013). The experiment of Rojo *et al*. (2005) was the first report in vivo where glucoamylase and amylase were used. The experiment of Lee *et al.* (2010) was selected because researchers combined buffer with glucoamylase to optimise the response of lambs and, finally, the document from Mendoza *et al.* (2013) was included because it combined the strategy of reducing levels of grain in the ration with the inclusion of glucoamylase to reduce costs.

Table 1. Main indicators used for economic evaluation of amylolytic enzymes

Total weight gain	Final weight - initial weight
Daily gain	Total weight gain / day period
Feed conversion	required kg feed / kg weight gain
Feed costs	Cost of diet or food provided to an animal
Diminished weight	Final weight - empty weight (kg lost during transport)
Wastage rate	100- (depleted Weight / Final weight) × 100
Breakeven	Total money has to sell an animal to cover production costs
Breakeven per kg	Cost of sales to breakeven / weight in kg
Profit margin	Sale price of the animal - Breakeven
Total Revenue	Sale price × kg weight of the animal for sale
Partial net income	Total Revenue - Total Costs
Income as % of income	(Partial Net income / Total Revenue) × 100

The composition of each experimental ration was calculated on a wet basis based on the dry matter content (Rogério *et al.*, 2012). Prices of ingredients, enzymes, additives, lambs, vaccines, cost of barbecue process, live weight, were obtained in the Valley of Mexico in the first months of 2015. With this information, profit margins were estimated per lamb in each experimental treatment including breakeven costs per kg of meat and the partial net income and profit expressed as a percentage of income when the lamb was processed as a barbecue or sold in a farm by live weight (Coffey and Laurent, 2014; Table 1). The economic analysis was conducted using the methodology from Meléndez and Ruiz (2007). The incomes (sales value) and expenditures (value of direct costs such as cost of animal, feed, veterinary costs, etc.) per lamb were calculated.

3. Results

The economic analysis of the first experiment where thermostable amylolytic enzymes were included in the rations is presented in Table 2. The inclusion of the enzyme increased feed cost by 12% and the profit margin was improved over the control by 7.25% with amylase and only 0.46% with glucoamylase when lambs were sold in live weight. The difference between treatments is lower if the lambs are processed to barbecue.

Table 2. Economic analysis of the inclusion of amylolytic enzymes in finishing lambs sell as lamb or processed as barbecue

	Control	Amylase	Glucoamylase
Duration of fattening days	56	56	56
Starting weight kg	27	27.86	27.5
Final weight kg	38.67	41.96	44.51
Kg daily gain	0.237	0.270	0.257
Kg total weight gain	11.67	14.10	17.01
Feed intake kg / d	1.559	1.740	1.638
feed conversion	6.58	6.44	6.37
Cost per kg feed US $	0.23	0.25	0.25
Feed costs US $	20.31	25.02	23.83
Weight sold (depleted) kg	37.90	41.12	43.62
Cost per kg purchase standing	2.19	2.19	2.19
Initial cost of animal US $	59.25	61.14	60.35
Cost of vaccines US $	3.08	3.08	3.08
Other costs per animal US $	0.68	0.68	0.68
Income from sale of sheep			
Breakeven US $	83.34	89.94	87.69
Breakeven / kg meat	32.07	31.89	29.31
Selling price US $ / kg	2.60	2.60	2.60
Profit margin by selling US $	0.40	0.41	0.59
Total sales revenues up US $	99.77	107.17	113.68
Partial net income per animal US $	15.42	17.22	25.99
% Total income	15.61	16.07	22.86
Reason revenue expenditure	1.18	1.19	1.29
Income from sale on barbecue			
Channel return%	49	49	49
Lamb barbecue kg	18.57	20.15	21.37
Barbecue process costs US $	34.29	34.29	34.29
Breakeven US $	115.24	121.83	119.58
Price barbecue US $ / kg	20.57	20.57	20.57
Profit margin	18.22	18.08	18.13
Total income US $	382.08	414.59	439.78
Partial net income per animal US $	266.84	292.75	320.19
% Total income	69.84	70.61	72.81
Reason revenue expenditure	3.32	3.40	3.67

The analysis of the second experiment (Table 3) shows that the use of buffer increases cost and is not profitable when combined with the enzyme. The inclusion of glucoamylase results in low profit margin (0.6% over the control when lambs are selling in farm).

The analyses of the third experiment (Table 4) indicate that the strategy combination of enzyme with decreasing grain was not profitable. It also shows that a reduction of grain level reduces the profits of the process of the feedlot process. In the three experiments, it was demonstrated that the lamb processed as barbecue significantly increased the utility of the producer.

Table 3. Economic analysis of the inclusion of amylolytic enzymes with buffer in fattening lambs by selling the finishing lamb or as barbecue.

	Control	Glucoamylase	Buffer	Enzyme + Buffer
Duration of fattening days	42	42	42	42
Starting weight kg	21	20.4	21.8	22.4
Final weight kg	32.13	31.44	33.68	34.37
Kg daily gain	0.265	0.263	0.283	0.285
Kg total weight gain	11.13	11.04	11.88	11.97
Feed intake kg / d	1.845	1.591	1.864	1.889
feed conversion	6.96	6.05	6.59	6.63
Cost per kg feed US $	0.24	0.27	0.24	0.27
Feed costs US $	25.42	24.70	25.99	29.62
Weight sold (depleted) kg	31.49	30.82	33.01	33.68
Cost per kg purchase standing	2.19	2.19	2.19	2.19
Initial cost of animal US $	46.09	44.77	47.84	49.16
Cost of vaccines US $	3.08	3.08	3.08	3.08
Other costs per animal US $	0.68	0.68	0.68	0.68
Income from sale of sheep				
Breakeven US $	75.28	73.24	77.61	82.55
Breakeven / kg meat	2.39	2.37	2.35	2.45
Selling price US $ / kg	2.60	2.60	2.60	2.60
Profit margin by selling US $	0.21	0.22	0.25	0.15
Total sales revenues up US $	82.06	80.31	86.04	87.78
Partial net income per animal US $	6.77	7.07	8.42	5.22
% Total income	8.21	8.81	9.79	5.96
Reason revenue expenditure	1.09	1.10	1.11	1.06
Income from sale on barbecue				
Channel return%	49	49	49	49
Lamb barbecue kg	15.43	15.10	16.18	16.50
Barbecue process costs US $	34.29	34.29	34.29	34.29
Breakeven US $	107.18	105.13	109.51	114.45
Price barbecue US $ / kg	20.57	20.57	20.57	20.57
Profit margin	18.38	18.43	18.34	18.24
Total income US $	317.46	310.70	332.84	339.59
Partial net income per animal US $	210.28	205.56	223.32	225.14
% Total income	66.24	66.16	67.10	66.30
Reason revenue expenditure	2.96	2.95	3.03	2.96

Table 4. Economic analysis of the inclusion of amylolytic enzymes and grain reduction in finishing lambs

	64% grain	60% grain + enzyme	60% grain
Duration of fattening days	42	42	42
Starting weight kg	21	20.4	21.8
Final weight kg	32.13	31.44	33.68
Kg daily gain	0.265	0.263	0.283
Kg total weight gain	11.13	11.04	11.88
Feed intake kg / d	1.845	1.591	1.864
feed conversion	6.96	6.05	6.59
Cost per kg feed US $	0.24	0.27	0.24
Feed costs US $	25.42	24.70	25.99
Weight sold (depleted) kg	31.49	30.82	33.01
Cost per kg purchase standing	2.19	2.19	2.19
Initial cost of animal US $	46.09	44.77	47.84
Cost of vaccines US $	3.08	3.08	3.08
Other costs per animal US $	0.68	0.68	0.68
Income from sale of sheep			
Breakeven US $	75.28	73.24	77.61
Breakeven / kg meat	2.39	2.37	2.35
Selling price US $ / kg	2.60	2.60	2.60
Profit margin by selling US $	0.21	0.22	0.25
Total sales revenues up US $	82.06	80.31	86.04
Partial net income per animal US $	6.77	7.07	8.42
% Total income	8.21	8.81	9.79
Reason revenue expenditure	1.09	1.10	1.11
Income from sale on barbecue			
Channel return%	49	49	49
Lamb barbecue kg	15.43	15.10	16.18
Barbecue process costs US $	34.29	34.29	34.29
Breakeven US $	107.18	105.13	109.51
Price barbecue US $ / kg	20.57	20.57	20.57
Profit margin	18.38	18.43	18.34
Total income US $	317.46	310.70	332.84
Partial net income per animal US $	210.28	205.56	223.32
% Total income	66.24	66.16	67.10
Reason revenue expenditure	2.96	2.95	3.03

Regarding the economic analysis per lamb, it was observed that the greater income was obtained with the glucoamylase addition, reaching a reasonable revenue expenditure of 1.29 (Table 2), indicating that investment is recovered and profit is generated with 29% utility. In the same trend, treatments with the inclusion of 60% grain plus amylolytic enzymes allowed a revenue expenditure of 1.24 to be obtained, while treatments with buffer and buffer plus amylolytic enzymes were the less profitable, with reasonable revenue expenditure rations of 1.11 and 1.06, respectively (Table 4).

Therefore, glucoamylase is the additive with greater impact on lamb production in intensive finishing.

During transformation as barbecue, the economics showed a similar response, where treatment with glucoamylase allowed heavier lambs weighing 44.51 kg live weight and with a carcass of 21.37 kg (Table 2) and therefore produced the greater amount of barbecue. Other factors that affected the final weight were initial live weight and length of the finishing feedlot; glucoamylase-fed lambs with 56 days and an initial weight of 27 kg were more productive than those with 45 days in feedlot and started with an initial weight of 23 kg (Tables 3 and 4).

4. Discussions

Results from Rojo *et al*. (2005) had the better performance results, particularly in the improvement of feed efficiency, which explains the difference between the other two experiments. Results of other experiments with the same enzymes (Crosby *et al*., 2006) have failed to identify the optimal dose but warned of the possibility that using those enzymes might cause subacute acidosis. Therefore, Lee *et al*. (2010) combined enzymes with buffers trying to obtain greater benefit from the amylolytic enzymes. The economic analysis in Table 3 indicates that the inclusion of glucoamylase had no benefits, as observed in the results from Rojo *et al*. (2005) in Table 2, and although the productive performance was improved with the addition of buffer, the combination of the two additives is expensive and reduces the margins that could only be compensated if the lambs are processed as barbecue.

Since biological results indicated that the amylolytic enzymes were very potent in the rumen and its inclusion caused subacute acidosis, the researchers decided to change the strategy, reducing the grain to include the enzyme whilst trying to maintain the same productive performance (Mota *et al*., 2011; Mendoza *et al*., 2013). In the experiment from Mota *et al*. (2011) a dose of 0.12% was used and reduced the level of grain by 12%, but Mendoza *et al*. (2013) lowered the grain level by 14% with the same dose, thereby obtaining economic benefits. The results in Table 4 show that the profit margin was similar when lambs are sold at the farm level and would have a minimal advantage in the profit margin (1%) if it is sold in barbecue. However, if grain prices rise too much, this strategy could be attractive. The results in Table 4 show that reducing grain level grain has an impact on profitability. When comparing the different experiments, it can be seen that the lambs' performance may be similar when grain levels are similar; however, the optimal level and biological levels of grain rations for finishing rations have not been determined (Mendoza *et al*., 2014).

The economic impact of enzymes is minor because feed costs represent 27% at the farm level and 17% if it is processed as barbecue, while the cost of the animal represents between 66% or 43% for farm or barbecue, respectively. In Brazil, it has been reported that the purchase of sheep represents between 40% and 48.5% of the costs (Rogéiro *et al*., 2007). In an intensive system in Colima Mexico, the lamb acquisition represented 50% and the feeding costs 43% (Macedo and Castellanos, 2004).

Sales prices in Mexico are higher than those in Brazil, where rations and production systems are based on pasture and by-products and production is lower (on average 1.63 US dollars) (Rogéiro *et al*., 2007); this is lower than estimated in Mexico in the control diets from the evaluated experiments, which are representative of intensive systems in central Mexico (on average 3.04 US dollars).

The ruminant grazing systems can significantly reduce feed costs (Granados *et al*., 2011), but the weight gain is reduced and the time to reach the live weight is prolonged, while the fat required to produce the barbecue is not optimal for the consumer (Mendoza *et al*., 2014); for example, systems can be at least 85 days (Macedo and Castellanos, 2004), whereas in central Mexico they are around 45-50 days.

Gonzalez *et al*. (2003) conducted an evaluation of the breakeven as a function of the number of lambs per litter and weaning weight and found that there is an inverse relationship between the breakeven point and the number of offspring and weaning weight, with the optimum being US $ 24.13 and the lowest US $ 59.24 per kg of lamb.

There are some studies in the literature with economic evaluation of feeding costs in different production systems not comparable with Mexican systems destined for barbecue (Caparra *et al*., 2007; Ermias *et al*, 2013). In a feedlot study from Tanzania (Shirima *et al*., 2012), low daily gains (94 g/d) were reported compared with those obtained in Mexican feedlots. There is information on economics of protein levels in intensive feedlots (Rogéiro *et al*., 2012). There are also reviews the use of exogenous enzymes that have been shown that can be unprofitable in cattle (Carreón *et al*., 2005).

The importance of processing the product until barbecue has been studied by Mondragón *et al*. (2014) in Mexico, and a profit margin of US $ 15.2/lamb was reported for processing and sales (representing 71% of the profits); in contrast, for the producer, this was only US $ 6.3/lamb (representing 29% of the profit) at the farm level, with a benefit/cost ratio of 1.0 to 1.3 at the farm or barbecue level, respectively. The cost benefit of that evaluated in this experiment was 1.23 on average at the farm level, and increased up to 3.23 for barbecue. Estimations of Granados *et al*. (2011) are similar for lambs sold in live weight from 1.32 to 1.35 in intensive systems.

Results indicate that the inclusion of exogenous amylolytic enzymes results in a very limited margin of profit. The price of grains will define if in a future it is profitable to add enzymes and reduce the level of grain at the same time. The profit margin when processing the barbecued lamb is greater than the sale of lambs at farm level in live weight.

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