CHAPTER 29

Summary of U.S. Grains Council Sponsored International Reduced-Oil DDGS Feeding Trials

Introduction

SEVERAL U.S. GRAINS COUNCIL (USGC) FEEDING TRIALS have been conducted to evaluate DDGS in Japan, Mexico, and Vietnam since 2010. This chapter provides a brief summary of the key findings of the trials. Additional information on USGC sponsored feeding trials from previous years are summarized in the third edition of the USGC DDGS Handbook published in 2012.

Recent Demonstration Trials in Japan

Swine

Effect of low-fat DDGS fed during the first half of fattening period on growth performance and carcass characteristics

ABSTRACT

An experiment was conducted at Nihon University, College of Bioresource Sciences in Japan to evaluate the effect of feeding swine low-fat DDGS on growth performance during the first half of the fattening period. The control group was not fed any DDGS in both the first half and the second half of the fattening period. The experimental group was fed 20 percent DDGS diet during the first half of the fattening period and both groups were fed the same diet during the second half of fattening period. The genetic background of the pigs used in this experiment were Landrace (L), Large White (W) and crossbred (LW) pigs (n = 67), and were divided into the control group and experimental group and fed their respective diets. The initial body weight was 50 kg, and the time period up to when they reached 75 kg in body weight was called the first half of the fattening period, and the period of time before reaching 115 kg in body weight was the second-half period, during which respective experimental diets were fed. Body weight, number of days fed experimental diets, carcass weight, backfat thickness, and grade were recorded for each pig. Nine Landrace barrows from each group were used for carcass analysis. The weight gain was favorable in both groups with average daily gain of 0.9 kg/day during the first half of the feeding period, and which was slightly decreased during the second half of the feeding period. There were no differences in feeding days, daily weight gain and feed conversion ratio between the two groups during the first half, second half or the entire feeding period. Also, there were no differences observed in carcass characteristics, analytical values of the carcass parts suitable for roasting including heat loss rate, texture, color tone (L*, a*, b*), fat melting point and fatty acid composition. The results indicate that feeding the 20 percent DDGS diet during the first half of the fattening period did not cause any negative effect on growth performance and provided the same level of productivity and carcass composition that would have been obtained with feeding standard diets in the Japanese pork industry.

MATERIALS AND METHODS

The objective of this study was to determine the effect of feeding a low-fat DDGS diet in the first half of the fattening period on swine growth performance and carcass characteristics. This feeding trial was implemented at the feedlot of Kanagawa Prefectural Pork Producers Association (Ebina City, Kanagawa Prefecture) from September 2015 to January 2016 (**Photo 1**).

Grouping and control of experimental pigs

A total of 67 pigs consisting of Landrace (L), Large White (W) and crossbred (LW) swine were divided into two groups: first group (25 head) starting the experiment on September 2015 and second group (42 head) starting on October 2015. The pigs within each group were allotted to either of the control group or experimental group, ensuring equal distribution in terms of breed, sex (sow/barrow) and body weight as much as possible, and then three pigs were housed in each cell. Ear tags were used for identification purpose. Starting with the initial body weight of 50kg, the period up to the time when the pigs would reach 75 kg was set as the first half of the fattening period and the period up to the time when they would reach 115 kg was as the second-half fattening period. During those periods, the pigs were fed respective diets. The first diet was replaced with the second diet when the average weight of the pigs in each cell reached 75 kg which was set as the first goal. Thereafter, when the weight of each pig reached115 kg, it was moved to a private cell and then shipped to a meat center. The pig was slaughtered on the day or next day of the shipment, and its carcass grade was recorded.

Experimental diets

The composition of experimental diets (**Photo 2**) is shown in **Table 1**. The control group was not fed any DDGS in both the first half and the second half of the fattening period. The experimental group was fed 20 percent DDGS diet during the first half of the fattening period and both groups were fed the same diet during the second half of fattening period. The diet of the experimental group for the first half of the fattening period was formulated so that TDN and protein were included at the same level as those of diets for the control group on the assumption that soybean meal, the main ingredient of the diets for the control group, was replaced.

Growth performance measurements

Body weight was measured every week and pigs with a weight close to the target weight for shipment (115 kg) were measured as appropriate. The feeding amount was measured for each group, and other measuring items such as age in days and daily weight gain were measured individually. Since all pigs in a cell were not always simultaneously shipped, the individual feeding amount for each was obtained by dividing the total feeding amount by the number of pigs remained in the cell as of the measuring day.

Carcass measurements

Carcass weight, backfat thickness and grade at the time of slaughter were recorded for all pigs. The carcass was analyzed using nine Landrace barrows each from the control group and experimental group. The part suitable for roasting in the left carcass of each was divided into three parts (shoulder, back and loin) and the back part was used for the analysis. The analytical items included heat loss rate, texture and color tone (L, a, b) of the eye muscle (ribeye) of the part for roasting (back), and color tone (L. a, b), fat melting point and fatty acid composition of the inner layer of back fat. The heat loss rate was calculated using the formula: weight of the lump of pork meat before heated – weight of the lump of pork meat after heated) / weight of the lump of pork meat before heated x 100. Texture was measured using a Tensipresser. Color tone was tested using a color-difference meter. Melting point of fat was measured by the method specified in the *Standard Methods of Analysis for Hygienic Chemists* (version of 1990). Fatty acid composition was analyzed by a gas chromatography.

Statistical analysis

The difference of average values between the control group and experimental group was confirmed by t-test.

RESULTS AND DISCUSSION

The general ingredients of the diets formulated for the experiment are as listed in **Table 2**. The experimental results of the pigs are summarized by breeding group and sex in **Table 3**. Barrows show fewer days required up to slaughter, greater daily weight gain and thicker backfat than sows. The results are similar to those commonly seen in the fattening performance of general swine on feed, and no difference in average values is observed between the breading groups. Therefore, the results described hereafter are obtained from the average values of all the pigs under experiment.

Growth performance

Weight gain is shown in **Table 4**. The experiment started with the body weight of 50 kg and the diet was changed to the one for the second half of the fattening period when the body weight exceeded 75 kg. After confirming that the weight reached 115 kg, pigs were shipped. The times for starting the experiment and changing diets were controlled using the average values of respective groups while shipment of pigs was individually controlled. This explains the smaller standard deviation of body weight at shipment. The fattening period is 82 days in total for each group, which shows no difference between the groups. Daily weight gain is 0.84 kg for the control group and 0.83 kg for the experimental group, which are similar. The final ages at slaughter also does not show any significant difference. The comparison between the first and second halves of fattening period shows favorable body weight gain in both of the experimental group and control group during the first half of the period, which are 0.93 kg and 0.96 kg, respectively, and a slight decrease in the second half period, 0.79kg and 0.76 kg respectively. Feed conversion ratios of both groups also show relatively low and good values of 3.37 and 3.11 during the first half of the period and aggravates up to 3.9. during the second period.

Carcass characteristics

No significant differences in carcass weight, dressing percentage or backfat thickness were observed between the two groups, which means the carcass characteristics show common values. As to the carcass grading, the percentage of upper grade carcass of each group is not high, but the percentage of middle grade carcass of the experimental group is higher than that of the control group, resulting in a higher percentage of lower-grade meat of the control group. The reason for carcass being excluded from the grading system was fat covering. The lower percentage of upper grade carcass as a whole is explained by the larger number of pureblood pigs than crossbred pigs used for the experiment due to reasons of the experimental farm. Although the reason for the higher percentage of middle grade carcass of the experimental group than the control group is unknown, the favorable average feed conversion ratio of the experimental group during the first half of the fattening period may contribute to achieving the suitable body form for the grading standards.

Nine Landrace barrows from each group were used for the analysis of meat quality of the part suitable for roasting, and the results of analyzing the eye muscle (ribeye) are shown in **Table 4**. There were no substantial differences in any items (**Photo 3**). **Table 5** shows the results of analyzing the inner layer of backfat of the part suitable for roasting. There are also no substantial differences in the analyzed items. The fat melting point is about 37℃ that is desirable and far from lower values of around 30℃ in which case the quality of fat is close to the level of so called loose fat. The results of the analysis of fatty acid composition (**Table 6**) also indicate a standard level of fatty acid composition that contains less polyunsaturated fatty acids (linoleic acid, linolenic acid, etc.), more monounsaturated fatty acid (oleic acid) and more saturated fatty acids (palmitic acid and stearic acid).

CONCLUSION

This study indicates that an inclusion of 20 percent low-fat DDGS in the diets fed to swine during the first half of the fattening period does not give any negative effect on fattening performance and keeps the productivity level equal to that of commonly used diets.

Table 1. Composition of Diets Formulated for Experiment (percent, as is basis)

	Diet for 1st half period		Diet for 2nd half period
	Control diet	Experimental diet	
Low-fat DDGS	-	20.00	-
Corn	56.28	47.73	56.22
Milo	20.00	20.00	20.00
Soybean meal	16.00	4.35	14.40
Bran	3.00	3.00	7.00
Fish meal (CP 65 percent)	2.00	2.00	-
Calcium carbonate	0.88	1.10	0.98
Dicalcium phosphate	0.41	0.15	0.48
Animal fat	0.50	0.50	-
Salt	0.30	0.30	0.30
L- Lysine hydrochloride	0.03	0.27	0.02
B-complex vitamins	0.20	0.20	0.20
Vitamin ADE	0.20	0.20	0.20
Microminerals	0.20	0.20	0.20
	100.00	100.00	100.00

Nutrient adequacy

(Values calculated based on the Feed Composition Table and Japanese Feeding Standard)

Total digestible nutrients (TDN)	104.0
Crude protein (CP)	103.0
Calcium	107.7
Lysine	108.8

Table 2. General Ingredients of Diets Formulated for Experiment (percent, as is basis)

		Diet for 1st half period		Diet for 2nd half period
	DDGS	Control diet	Experimental diet	
Moisture	15.3	13.3	13.3	13.3
Crude protein	26.9	14.9	14.2	13.2
Crude fat	9.7	4.3	5.7	4.2
Crude fiber	5.3	1.8	2.1	2.0
Soluble nitrogen-free extract	38.4	61.9	60.9	63.6
Ash	4.4	3.8	3.8	3.7

Table 3. Comparison of Results by Breeding Group and Sex

	Sex	Number of animals	Ages at slaughter (day)	Daily weight gain (kg)	Backfat thickness (cm)
Control group					
Landrace (L)	Gilt	8	203	0.76	2.0
	Barrow	9	185	0.89	2.6
Large White (W)	Gilt	8	189	0.86	2.3
	Barrow	5	187	0.86	2.3
Crossbred (LW)	Gilt	1	185	1.04	2.3
	Barrow	2	193	0.88	3.1
Experimental group					
Landrace (L)	Gilt	8	200	0.80	2.2
	Barrow	9	188	0.87	2.6
Large White (W)	Gilt	7	192	0.82	1.9
	Barrow	4	190	0.88	2.3
Crossbred (LW)	Gilt	5	194	0.85	2.4
	Barrow	1	185	0.93	3.0

Table 4. Weight Gain and Carcass Characteristics		
	Control group (n=33)	**Experimental group (n=34)**
Body weight at start (kg)	50.1 ± 5.8	49.6 ± 6.6
Body weight at diet change (kg)	78.2 ± 6.1	79.2 ± 7.0
Body weight at shipment (kg)	117.2 ± 3.0	116.9 ± 2.7
Fattening period (days)	82 ± 14	82 ± 12
1st half	31 ± 5	32 ± 6
2nd half	51 ± 12	50 ± 11
Feeding amount (kg)	245.2 ± 47.5	235.8 ± 34.1
1st half	92.1 ± 20.3	89.9 ± 15.0
2nd half	153.1 ± 43.8	145.9 ± 32.3
Daily weight gain (kg)	0.84 ± 0.11	0.83 ± 0.09
1st half	0.93 ± 0.27	0.96 ± 0.21
2nd half	0.79 ± 0.14	0.76 ± 0.13
Feed conversion ratio	3.61 ± 0.60	3.49 ± 0.38
1st half	3.37 ± 0.93	3.11 ± 0.69
2nd half	3.94 ± 0.93	3.95 ± 0.90
Slaughter age (days)	192 ± 19	193 ± 16
Carcass weight (kg)	77.5 ± 3.0	77.8 ± 2.4
Dressing percentage (%)	66.1 ± 1.7	66.5 ± 1.4
Backfat thickness (cm)	2.4 ± 0.6	2.3 ± 0.5
Grade (number of heads)		
Upper	6	5
Middle	14	19
Lower	10	7
Out of grade	3	3

Average ± Standard deviation

There were no signficant differences between dietary treatments for all measurements

Table 5. Heat Loss, Texture and Color Tone of Eye Muscle (Ribeye)		
	Control group	**Experimental group**
Heat loss (drip rate) %	7.2 ± 1.4	8.4 ± 1.2
Texture		
Hardness (kg/cm^2)	7.95 ± 0.76	8.37 ± 1.20
Cohesiveness	0.50 ± 0.03	0.51± 0.03
Elasticity %	81.2 ± 1.6	80.8 ± 1.6
Adhesiveness (cm^2/cm^2)	0.00 ± 0.01	0.00 ± 0.00
Color tone		
L	51.8 ± 2.7	51.9 ± 2.6
a	10.5 ± 1.1	10.4 ± 0.8
b	10.8 ± 1.2	10.6 ± 1.0

Average ± standard deviation n = 9

There were no signficant differences between dietary treatments for all measurements

Table 6. Color Tone, Melting Point and Fatty Acid Composition of Inner Layer of Subcutaneous Fat		
	Control group	**Experimental group**
Color tone		
L	80.3 ± 1.5	79.5 ± 0.9
a	6.7 ± 1.4	6.8 ± 1.0
b	9.9 ± 1.9	10.4 ± 1.8
Fat melting point (℃)	37.7 ± 1.3	37.0 ± 1.9
Fatty acid composition %		
10:0 (Decanoic acid)	0.1 ± 0.0	0.1 ± 0.0
12:0 (Lauric acid)	0.1 ± 0.0	0.1 ± 0.0
14:0 (Myristic acid)	1.3 ± 0.1	1.4 ± 0.1
16:0 (Palmitic acid)	27.0 ± 0.7	26.9 ± 0.8
16:1 (Palmitoleic acid)	1.5 ± 0.2	1.6 ± 0.2
17:0 (Heptadecanoic acid)	0.3 ± 0.1	0.3 ± 0.1
18:0 (Stearic acid)	16.8 ± 1.0	15.9 ± 0.9
18: 1(n9) (Oleic acid)	39.4 ± 0.8	39.4 ± 1.2
18:2 (n6) (Linoleic acid)	7.7 ± 0.6	6.7 ± 0.7
18:3 (n3) (Alpha-linolenic acid)	0.4 ± 0.0	0.4 ± 0.1
20:0 (Arachidic acid)	0.3 ± 0.0	0.3 ± 0.0
20:1 (Icosenoic acid)	1.1 ± 0.1	1.0 ± 0.1
20:2 (n2) (Icosadienoic acid)	0.4 ± 0.1	0.4 ± 0.1
20:4 (n6) (Arachidonic acid)	0.1 ± 0.0	0.1 ± 0.0

Average ± standard deviation n = 9

There were no signficant differences between dietary treatments for all measurements

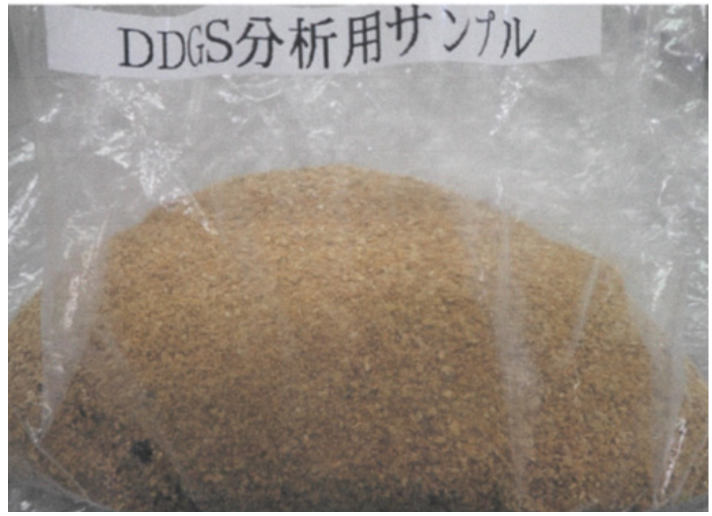
Photo 1. Site of Feeding Experiment

Pigpen

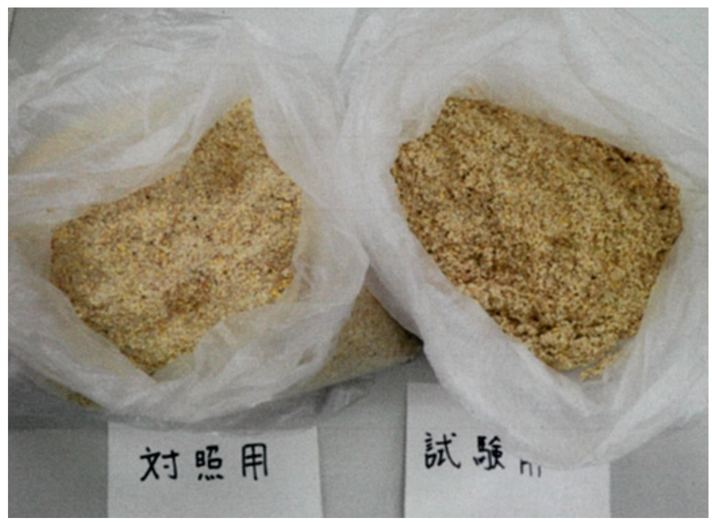
Cell

Measurement of body weight

Photo 2. DDGS Samples and Diets



DDGS (experiment sample)



Control diet and experimental diet for first half period

Feedstuff

Photo 3. Carcass

Cuts suitable for roasting

Recent Demonstration Trials in Mexico

Beef Cattle

TRIAL 1

A demonstration study was conducted in 2014 to evaluate supplementing diets with one kilogram of DDGS per day or a concentrate containing meat and bone meal and DDGS on growth performance and compensatory growth of the bulls under different weather conditions. It is well known and documented that meat and bone meal has a very low digestibility, and in several companies the use of ruminant meat and bone meal in ruminant diets is not allowed because of the concern of transmission of BSE. The results from this demonstration trial are shown in **Figure 1**. Although the bulls fed DDGS began the trial with almost 38 kg less body weight, by the end of the trial they weighed about 24 kg more the bulls on the control treatment.

There are several important aspects regarding the improvement in average daily gain observed when feeding supplemental DDGS to these bulls. First, these bulls were extremely underfed and had a very low plane of nutrition. Both the control and DDGS supplemented groups arrived with the same body conditions. Once the bulls were adapted to the new paddocks and fed the supplement, they exhibited an extraordinarily high average daily gain (test day 29) that may be explained as compensatory growth (**Figure 2**). Secondly, by the second test weigh date (day 55), the weather conditions were hot and dry, reducing the available forage resulting dramatically reduced average daily gain. However, in both feeding periods, the bulls fed supplemental DDGS gained 500 more grams/day in each period. As a result, providing the DDGS supplement increased net income by about $15/day (**Table 1 and Figure 3**). In addition to the economic benefits of using the DDGS supplement, at the end of the feeding trial, the control bulls weighed 24.5 kg less, and were gaining only 0.48 kg/day. Therefore, the control bulls required an additional 51 days to reach the same final weigh of the bulls fed the DDGS supplement. At times of the year when beef feedlots require large numbers of cattle; the price increases to meet this demand. Because of feeding the DDGS supplement, this producer had a great opportunity to sell heavier animals which were already adapted to start eating from a feed bunk. This advantage may result in five days less time at the feedlot for adapting to feeding, which is an economic benefit of about $15.24 pesos per animal per day.

Another feeding trial was conducted with beef producers near the Albagran feed mill in 2016. A group of DDGS users was formed, and cattle from different producers were transported to a single feedlot. Cattle weighing less than 230 kg receive the highest price and were used in this demonstration trial. A total number of 51 young crossbred bulls were housed in two feedlot pens (No. 6 and No.7). Once the bulls were received at the feedlot, they were checked by a veterinarian and admInistered several vaccines and vitamins, and sorted according to body weight into each pen, with light weight bulls (136 kg) being placed in pen No. 6 and the heavy bulls (168 kg) placed in pen No.7. During the first day, all bulls were fed 70 percent of formulated diet as an adaptation period. All animals in each pen had free to access to water and to the total mixed ration (TMR). The concentrate and TMR formulation is shown in **Table 2**. The bulls were fed at two to three times daily and individually weighed during the 53 day trial. Bulls consumed an average of 7 kg of TMR/ day and overall average daily gain was 1.17 kg/day. Final body weights were 194 kg for light weight bulls and 234 kg for heavy weight bulls. The economic evaluation showed that feeding

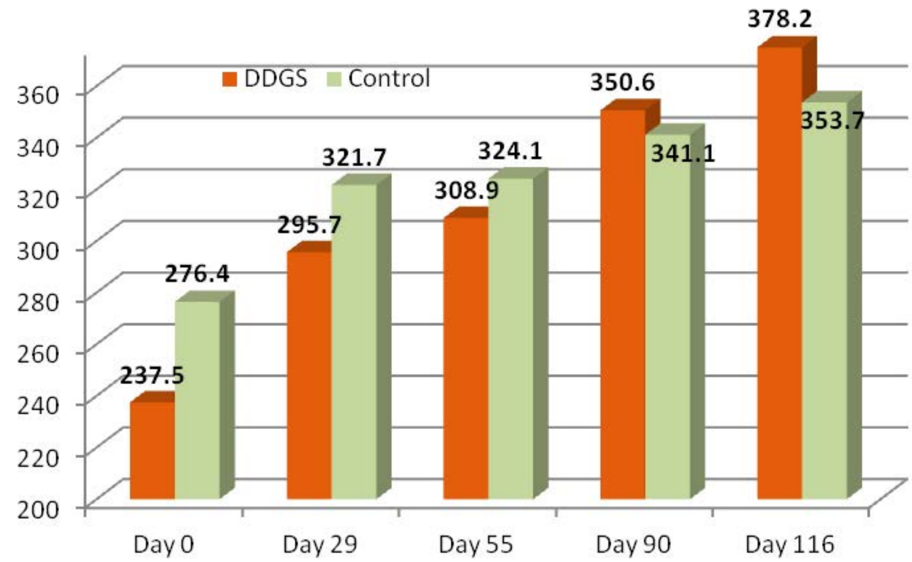


Figure 1. Initial body weight (kg) and subsequent body weights of bulls fed supplemental DDGS from February 28 to June 24, 2014

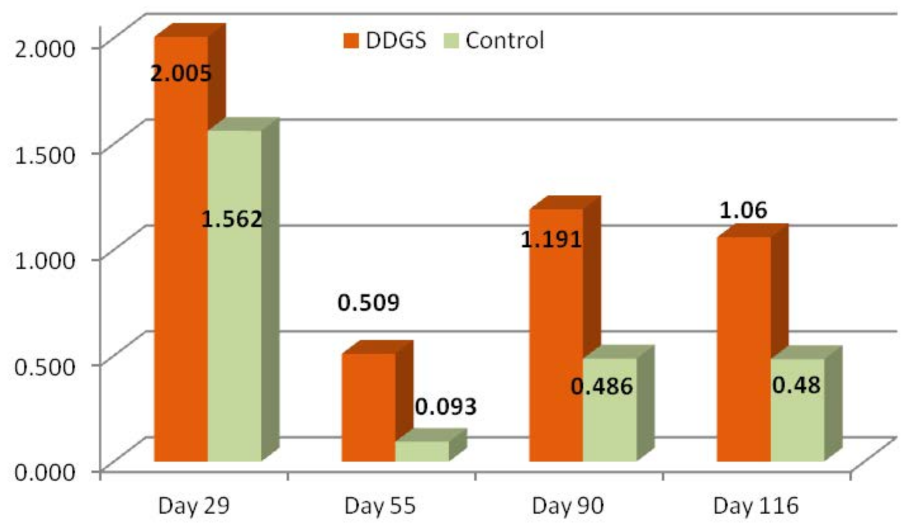


Figure 2. Average daily gain of bulls fed supplemental DDGS compared to the control group from February 28 to June 24, 2014

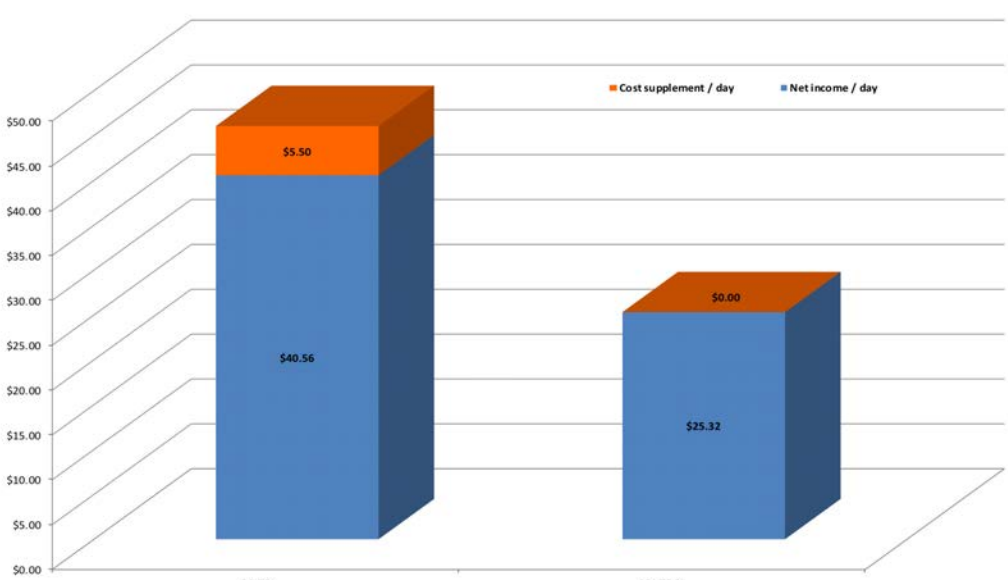


Figure 3. Average net income (Mexican pesos) per day per animal

Table 1. Summary of growth performance and economics of feeding supplemental DDGS to bulls

	DDGS	Control
Initial weight (kg)	237.5	276.4
Final weight (kg)	378.2	353.7
kg gained	140.6	77.3
Total days	116	116
ADG kg	1.212	0.666
$/kg live weight	$38.00	$38.00
Gross income/day	$46.06	$25.32
Cost supplement/day	$5.50	
Net income/day	$40.56	25.32

the DDGS concentrate resulted in a gross income of $61.03/day/bull Mx pesos, and subtracting the input costs of $40.49/day/bull Mx pesos, resulted in a net Income of $20.54 Mx pesos/day/animal (**Table 3**).

TRIAL 2

A demonstration study was also conducted in 2017 with replacement heifers in Tierra Colorada, Veracruz. In the state of Veracruz, most of the ranches are dedicated to the milk production as a cow calf operation or dual purpose farming, where the cow is milked three teats once daily, and the fourthteat is left for the nursing calf. These types of farms also raise the calves until they reach a wide range of live weight from 225 kg to 400 kg. The decision to sell the calves over this weight range is based on the economic needs of the farmer, and the price paid for these types of calves. However, every year the demand for replacement heifers remains. fairly constant and there is almost no management control of these animals. Although there are general guidelines to raise the replacement heifers, but most producers seem knowledgeable but others do not provide much attention to the heifers. Ideally replacement heifers must reach 60 percent of the mature body weight by the age of 15 months, and have a minimum hip height of 145 cm to be considered for first service. Most of the mature cows in Tierra Colorada average 555 kg. Therefore, 60 percent of this body weight is 330 kg, which is used as a general indicator that achieving a body weight of 350 kg at 15 months of age is the target to get heifers pregnant for the first time.

In December of 2016, the owner of this ranch agreed to conducting a DDGS feeding trial with a group of 100 replacement heifers. The initial age and body weight range of these heifers is shown in **Table 4**. A comparison of actual to ideal body weight of heifers at the Tierra Colorada ranch is shown in **Figure 4**.

The trial began with 100 virgin replacement heifers from a wide range of ages and weight, with the objective of comparing the current feeding practices with a proposed one involving feeding high levels of DDGS to increase average daily gain and reach the ideal body weight for first service on the right age. However, because infeasible to have different groups according to the age of the animals, heifers were sorted by body weight into two groups consisting of light body weight (50 heifers, 214 kg average initial body weight, and average age of 13.3 months) and the heavy body weight (50 heifers, 275 kg average initial body weight, and average age of 16.6 months).

Table 2. Concentrate and total mixed ration formulation

Ingredient	kg / MT
Concentrate Formula	
DDGS	350
Steam flake yellow corn	328
Wheat bran	110
Sugarcane molasses	100
Soybean meal	85
Mineral premix	27
Total	1,000
Total Mixed Ration TMR	
Chopped grass hay	165
Concentrate	835
Total	1,000

Table 3. Economic evaluation of DDGS feeding program for gowing bulls	
Purchasing price/kg	$52.00
Selling price/kg	$52.00
Initial weight kg	150.6
Final weight kg	212.8
Supplement/animal/day kg	7.1
Average daily gain kg	1.174
Bank interest	$2.610
Cost supplement/animal/day	$32.802
Miscelaneus costs	$5.074
Total inputs	$40.486
Gross income	$61.026
Net income	$20.540
Feeding days	53.0
Total Money Invested/Period	
$/Bank interest period	$138
$/DDGS supplement period	$1,739
$/Miscellaneous period	$269
Sub total	$2,146
Purchasing money/bull	$7,831
Total amount money/period	$9,977
Gross income	$11,066
Difference	$1,089
Turn over money/year	6.887
Net income/year	$7,497
Cost/kg gained	$34.50

Table 4. Initial age and body weight of heifers at the beginning of the field demonstration trial in Tierra Colorada, Veracruz

Age range months	Number of heifers	Average body weight kg
8 to 10	12	206
11 to 12	22	238
13 to 14	11	228
15 to 16	25	256
17 to 18	24	282
19 to 20	5	300
21 to 22	1	240
Total	100	254

Heifers in both of these groups had been underfed with low average daily gain. For one month after beginning the trial, heifers were fed according to the traditional feeding practices, which consisted of only grazing grass pasture. After this initial month, all heifers were weighed, and the light heifers gained only 4.4 kg while the heavy heifers gained 10.6 kg during this one month period. With this low weight gain, it would require 951 days for the light weight heifers to reach 350 kg in body weight and 198 days for the heavy weight heifers. With this information, the farmer realized that the grass pastures were not providing enough forage to support a minimal 0.65 kg daily gain.

Although it is extremely difficult to calculate the actual dry matter intake from grass pastures, a forage and concentrate mixture was formulated for these heifers that included DDGS (**Table 5**). The amount of this mixture that was offered changed during the trial and was based on the average daily gain (ADG) of the heifers each month. The cost was $3.878

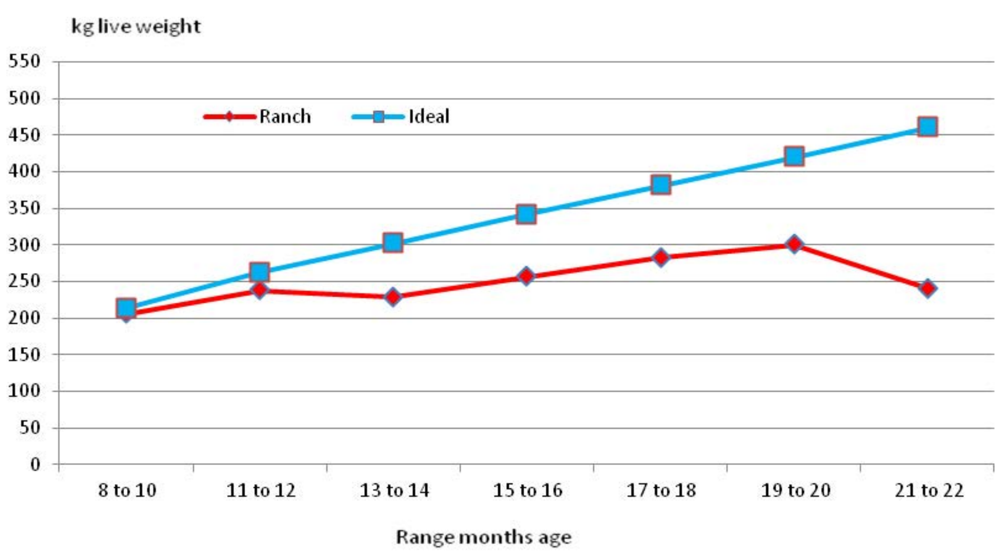


Figure 4. Comparison of actual to ideal body weight of heifers at the Tierra Colorada ranch

Table 5. Diet composition fed to replacement heifers

Mx $ / MT	Ingredient	kg / MT
650	Corn silage	100
4,035	Yellow corn	350
4,673	DDGS	405
2,725	Sugarcane molasses	125
10,156	Mineral premix	20
	Total	1,000

Mx pesos per kg and was offered at 3.5 kg per animal per day, which resulted in a cost of $13.573 Mx pesos per animal per day. The trial was conducted for 151 days until May 19, 2017.

The initial daily gain recorded on January 20, 2017 served as a reference for the demonstration. The light heifer group began with an average initial body weight of 219 kg and had an average final body weight of 313 kg. The heavy heifer group had an initial body weight of 285 kg and a final average body weight of 393 kg. Therefore, the light weight heifers gained 94 kg and the heavy weight heifers gains 108 kg during the 199 day feeding period, which resulted in an ADG of 0.79 kg/day and 0.90 kg/day for the light and heavy heifer groups, respectively. During the month of April, the entire heavy weight group reached the 350 kg and began their reproductive program. By January 20, 2017, this group was projected to reach the 350 kg in January 2018 (198 days), according to the previous daily gain; in contrast with 94 days needed to reach the 350 kg during the present demonstration, which represents a 104 days less to start the reproductive program. In comparison, the light weight heifer group still needed 153 days to reach the 350 kg, compared with the 951 days projected when the demonstration started. **Figure 5** shows the average body weight increase during the demonstration trail for replacement heifers fed the DDGS diet at Ranch Tierra Colorada, and **Figure 6** shows the reduction in the number of days to reach 350 kg body weight. By the end of the demonstration period, almost all of the heifers reached the desired body weight according to their age. **Figure 7** shows the ideal age and body live weight (blue line), the red line shows the original increase in body weight of the light weight heifer group according to heifer age prior to the trial, and the green line shows the time point when heifers reached 350 kg for first service.

Table 6 and 7 show the economic comparison of providing the DDGS supplement to replacement heifers on this ranch. For both heifer groups, the net income was dramatically increased by feeding the DDGS supplement to these heifers, with the light weight heifers going from a loss to a net profit.

TRIAL 3

USGC DDGS field demonstration in Ozuluma Veracruz from February 23 to June 26, 2017

The Veracruz state is almost 850 km long (528 miles) surrounding the Gulf of Mexico. The west side of the state is located the Sierra Madre Oreintal and on the east side the Mexican Gulf shore. This particular geographic location allows the Veracruz state to receive large amounts of rainfall

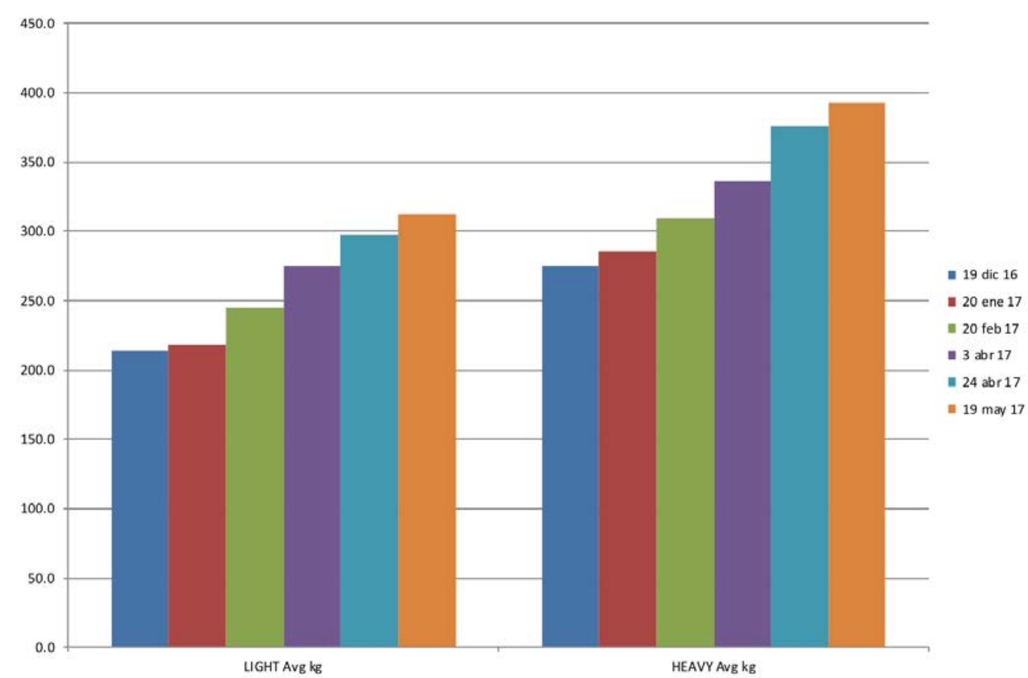


Figure 5. Comparison of the average body weight increase of light and heavy weight replacement heifers during the DDGS demonstration trial at Ranch Tierra Colorada

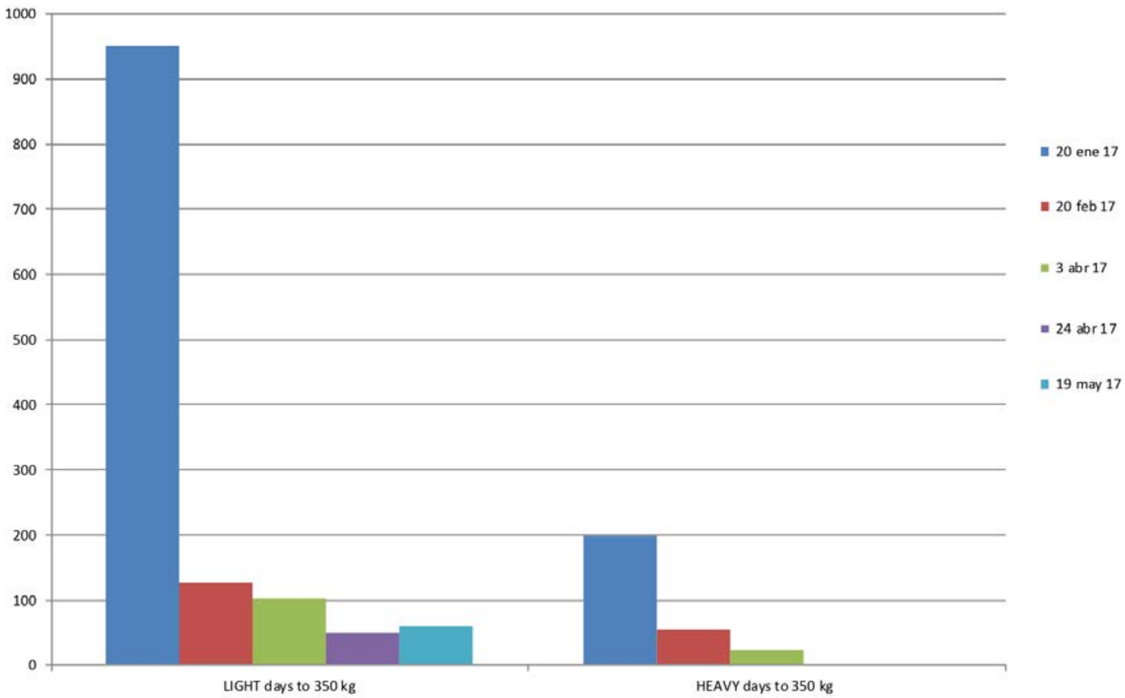


Figure 6. Comparison of the reduction in the number of days to reach 350 kg of light and heavy weight replacement heifers during the DDGS demonstration trial at Ranch Tierra Colorada

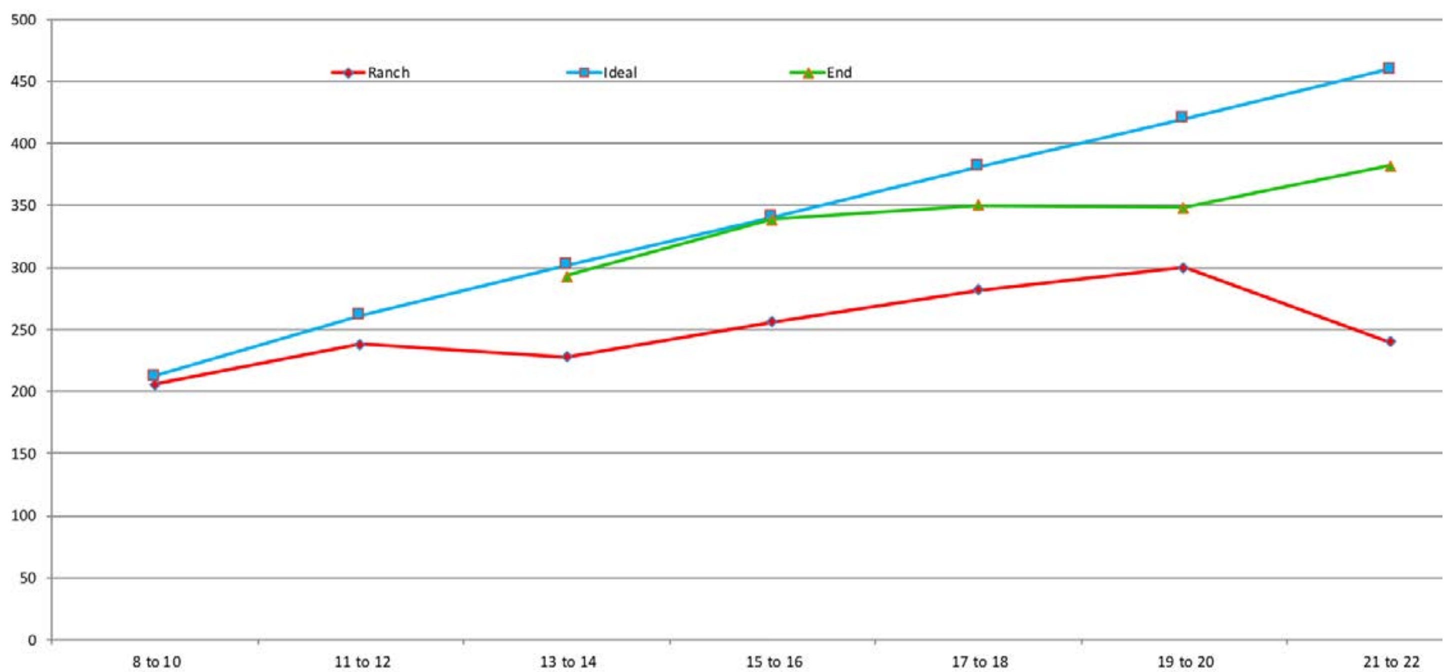


Figure 7. Comparison of the weight gain scenarios to reach ideal body weight (350 kg) of replacement heifers during the DDGS demonstration trial at Ranch Tierra Colorada

Table 6. Economic cost summary of the light weight heifer group

DAILY COSTS		
Daily supplement kg / animal	0	3.5
Daily Gain kg	0.138	0.791
Bank Interest 10% yr	$2.186	$2.186
Paddock rent / grass	$4.250	$4.250
Supplement 3.5 kg / animal	$0.000	$13.573
Extras	$1.500	$1.500
Total	$7.936	$21.509
Gross income	$4.968	$28.476
Balance	-$2.968	$6.967

Feeding days to target weight	952.2	166.1
Initial weight	218.6	218.6
Final weight	350.0	350.0

TOTAL INVESTED MONEY / PERIOD		
$/period interest bank	$2,081	$363
$/period paddock rent	$4,047	$706
$/period DDGS supplement	$0	$2,255
$/period extras	$1,428	$249
Total	$7,556	$3,573
$ purchasing / animal	$7,870	$7,870
Total invested money / period	$15,426	$11,443
Total income 350 kg X $36/kg	$12,600	$12,600
Diference	-$2,826	$1,157
Money turn over / year	0.383	2.197
Net income / year	-$1,083.3	$2,543.0
Cost / kg gained	$57.51	$27.19

Table 7. Economic cost summary of the heavy weight heifer group

DAILY COSTS		
Daily supplement kg / animal	0	3.5
Daily Gain kg	0.326	0.902
Bank Interest 10% yr	$2.750	$2.750
Paddock rent / grass	$4.250	$4.250
Supplement 3.5 kg / animal	$0.000	$13.573
Extras	$1.500	$1.500
Total	$8.500	$22.073
Gross income	$11.736	$32.472
Balance	$3.236	$10.399

Feeding days to target weight	230.1	83.1
Initial weight	275.0	275.0
Final weight	350.0	350.0

TOTAL INVESTED MONEY / PERIOD		
$/period interest bank	$633	$229
$/period paddock rent	$978	$353
$/period DDGS supplement	$0	$1,129
$/period extras	$345	$125
Total	$1,956	$1,835
$ purchasing / animal	$9,900	$9,900
Total invested money / period	$11,856	$11,735
Total income 350 kg X $36/kg	$12,600	$12,600
Diference	$744	$865
Money turn over / year	1.587	4.390
Net income / year	$1,181.1	$3,795.6
Cost / kg gained	$26.07	$24.47

during the year. Along the 850 kg, it can be divided into three sections: North, Central and South, with each section differing in latitude and weather conditions.

The north region is dryer and cold compared with the other two regions, which allows the beef and milk producers to use cross breed cebu X European breeds like Charolais, Angus, Montbeliade, Simmental, Braunvieh, European Swiss, etc. These types of animals are preferred by the feedlots. The favorable weather conditions for the European type beef also are against the forage production; the grass paddocks usually produce limited amounts of low digestible forages. The net result of these combinations are high genetic merit of the animals with a low plane of nutrition, which leads to different undesirable conditions, such as low daily gains, reduced milk production and failure to breed the cows every year.

In this first attempt to work with the beef and milk producers from the north of Veracruz promoting the use of DDGS, DDGS was not used as a concentrate, but was blended with digestible forage due to the low availability and indigestibility of forages from the grass pastures. If the animals were not capable of maximizing dry matter intake, almost any concentrate will be insufficient to show the genetic potential of these animals. January to May is the dry and cold season, with a lack of good forages, and the price paid for the calves less than 230 kg is the highest compared with heavier animals.

Therefore, a producer from Ozuluama Veracruz was asked to conduct a DDGS field demonstration. A total of 32 animals were sorted into two groups with an initial average body weight of 99.8 kg each group. Group 1 (Potrero) received the traditional feeding practices and management and group 2 (DDGS) received the high DDGS ration in a 100 percent confinement with ad libitum access to water. Each group consisted of nine heifers and seven young bulls **Table 1**. Diet formulations are shown in **Table 2** and feeding practices are shown in **Table 3**. Animals from Group 1 were allocated on grass paddocks and offered some commercial concentrate 1.0 kg plus some fresh citrus pulp, once a day. One additional benefit for Group 1 animals, these animals have more square meter of grass every day, since 13 animals were placed in 100 percent confinement. During the first weeks after the start of the demonstration, three animals from each group were

Table 1. Distribution of sex and body weight between the two experimental groups

Rancho Paisaje, Ozuluama Veracruz February 23, 2017

Group	Sex	ID Number	kg	Group	Sex	ID Number	kg
1	female	3740	70	2	female	3715	75
1	female	3729	83	2	female	3724	80
1	female	3747	95	2	female	3741	94
1	female	8301	97	2	female	3728	98
1	female	3726	98	2	female	8299	100
1	female	3745	107	2	female	3730	107
1	female	3717	109	2	female	8303	108
1	female	3718	110	2	female	8353	112
1	female	3723	147	2	female	3720	124
1	male	5347	50	2	male	8319	64
1	male	3739	88	2	male	3738	71
1	male	3742	90	2	male	3744	90
1	male	3791	93	2	male	3746	100
1	male	3725	104	2	male	8307	114
1	male	8356	116	2	male	3716	123
1	male	8311	139	2	male	3727	136
		kg Total	**1,596**			**kg Total**	**1,596**
16		**kg average**	**99.75**	16		**kg average**	**99.75**

Table 2. Diet formulation of DDGS calf starter (18 percent crude protein) and ration for Group 2

Ingredient	**kg / MT**
Calf Starter (18% Crude Protein)	
DDGS	480
Ground yellow corn	300
Sugarcane molasses	100
Corn pericarp	90
Vitamin & mineral premix	30
Total	1,000
Ration	
Calf Starter	680
Chopped grass hay	230
Sugarcane molasses	90
Total	1,000

Table 3. Feeding practices

From	**23 Feb 17**	**28 Mar 17**	**27 Apr 17**	**24 May 17**
Until	**28 Mar 17**	**27 Apr 17**	**24 May 17**	**26 Jun 17**
kg ration / day / animal	3.5	4.5	5.5	6.5
Concentrate	2.39	3.07	3.75	4.43
Chopped grass hay	0.80	1.02	1.25	1.48
Sugarcane molasses	0.32	0.41	0.50	0.59

removed and kept under different management conditions. During the first 33 days, approximately 10 days were used to adapt the Group 2 animals to the 100 percent confinement. However, the group fed DDGS showed a better performance and we began to calculate the number of days needed to reach the desire body weight, considering the average daily gain (kg). The number of males and females in each group remain constant for the entire demonstration and the growth rates of remaining cattle in each group are shown in **Table 4**.

Approximately every 30 days, all the animals (group 1 and 2) were individually weighed and weight were recorded. After the fourth test weight (May 24), several animals from group 2 were very close to the 230 kg and it was decided to sell them before they exceeded 230 kg live weight. Once these cattle were sold, the extra young animals were added to take their place along with 13 of the original animals from group 1 until June 26. **Figure 1** shows the average body weight, **Figure 2** shows the kilogram gained, and **Figure 3** shows the average daily gain for each dietary treatment. Results from this study show the benefits of feeding high amounts of DDGS combined with forage to improve average daily gain (in kg) over the control group fed no DDGS. Furthermore, the cost of production is also reduced by feeding DDGS.

Every day, the animals in the DDGS treatment (group 2) required an extra investment, but the daily net income was greater for this group with $11.21 Mx pesos per animal. All the ranches have the goal of producing more liters of milk liters or kg of beef in the least amount of time. According to the traditional management, these animals (Group 1) would require approximately 206 days to reach 230 kg and the Group 2, almost 100 days (not considering the animals that finished earlier). It is important to note that the number of turnovers of the money per year. Every time an animal is sold, regardless of which treatment group, the farmer will realize a positive difference of $2,700 Mx pesos from Group 1 compared with the $2,408 from Group 2. Although most producers believe that it may be more economical to not feed extra supplement, the data from this trial clearly show that these positive economic benefits can be realized only 1.77 times per year for Group 1 animals, compared with 3.77 times per year from Group 2 animals. Therefore, every year, the animals from group 1 generate $4,769.1 Mx pesos compared with $8,860.8 from animals of Group 2. Not only is the daily gain (kg) important, but also is the time involved in reaching desired body weights in commercial beef production systems.

Table 4. Growth rate of cattle during the second weigh period

Rancho El Paisaje									
			Days interv	33					
		Weight test	23-feb-17	28-mar-17					
			kg	kg	kg gained	ADG kg	Days to 230 kg	Male	Female
Control group		Average 1	105.0	124.7	19.7	0.597	176.5	4	9
DDGS group		**Average 2**	**105.7**	**135.7**	30.0	0.909	103.7	5	8

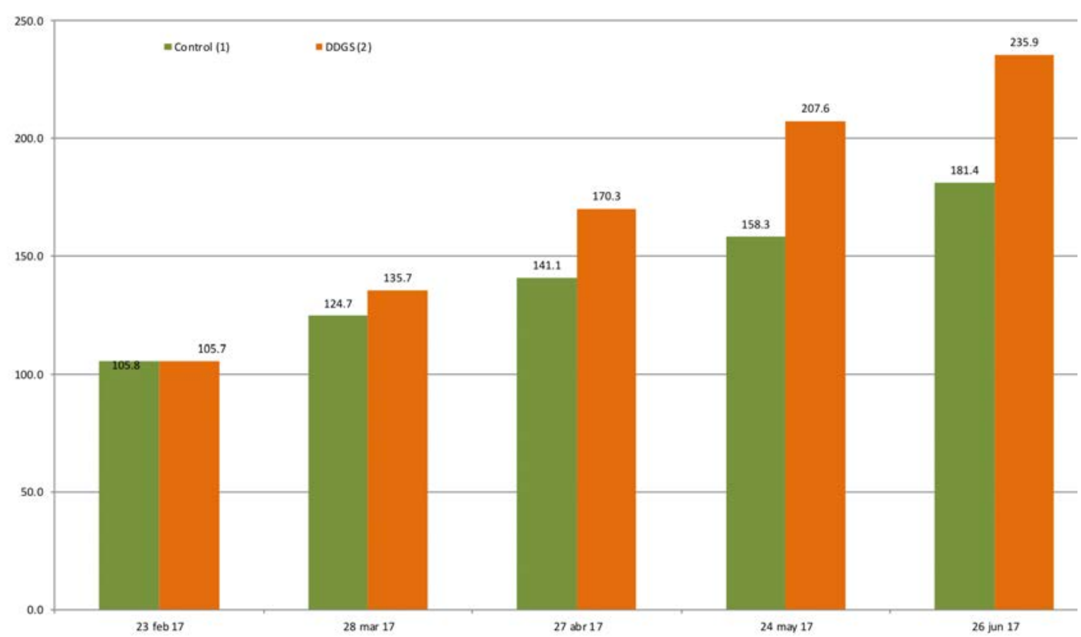


Figure 1. Effect of dietary treatment on cattle body weight throughout the feeding period

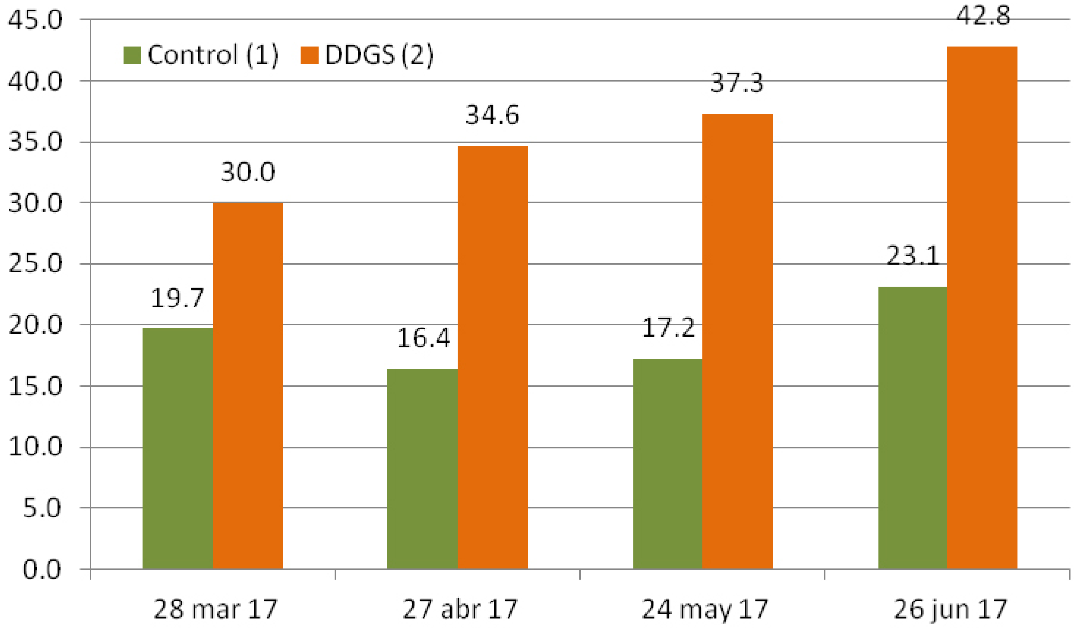


Figure 2. Effect of dietary treatment on cattle body weight gain (kg) throughout the feeding period

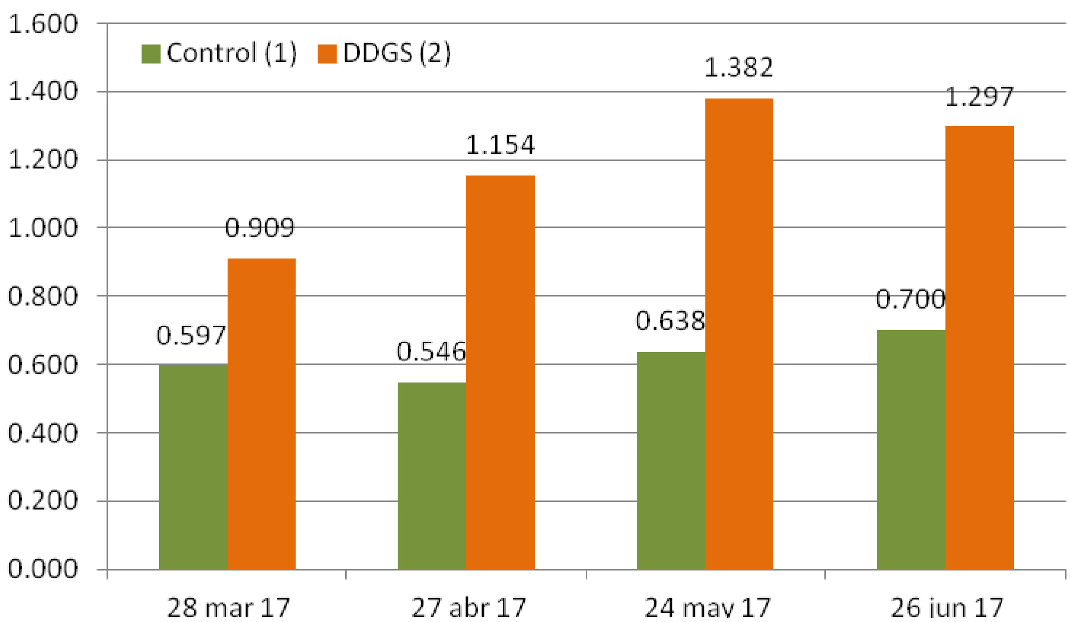


Figure 3. Effect of dietary treatment on cattle average daily gain (kg) throughout the feeding period

TRIAL 4

USGC DDGS field demonstration in Ozuluama Veracruz from February 24 to June 27, 2017 at Los Sierra ranch

The Veracruz state is almost 850 km long (528 miles) surrounding the Gulf of Mexico. On the west side of the state is located the Sierra Madre Oriental, and the Mexican Gulf shore is on the east side of the state. This geographic location allows the Veracruz state to receive large amounts of rainfall during the year, but along the 850 km, the state can be divided into the north, central and south regions which differ in latitude and weather conditions. The north region is dryer and colder compared with the other two regions, and these weather conditions allows the beef and milk producers to use cross breed Cebu × European breeds like Charolais, Angus, Montbeliarde, Simmental, Braunvieh European Swiss, etc., which are preferred by the feedlots. However, the favorable weather conditions for raising the European type beef breeds do not match forage production capabilities because the grass pastures usually produce limited amounts of low digestible forages. The net result of this combination is high genetic merit of the animals but they are provided a low plane of nutrition. As a result, several undesirable effects occur such as low daily gains, reduced milk production and low pregnancy rates of cows every year.

In this first attempt to work with the beef and milk producers from the north of Veracruz, the Council promoted the use of DDGS not as a single concentrate, but to blend with digestible forage due to the low availability and indigestibility of forages from the pastures. If the animals are not able to maximize dry matter intake, almost any concentrate will be insufficient to allow the genetic potential of these animals to be maximized. During the months from January to May, the dry and cold season occurs with the lack of good forages, and the price paid for the calves less than 230 kg is the greatest compared with heavier animals.

At the Los Sierra ranch, about 60 cows are milked once daily and the milk is sold to a local cheese plant. The owners of this ranch also raise yearling bulls on grass pastures. Depending on live weight price paid for the yearling bulls, the decision to sell them is based on when the animals reach 350 kg or 400 kg in body weight. In this demonstration study, several groups of young bulls with average body weights of 100, 150, 200, 250, 300 and 350 kg. Therefore, the trial was conducted to compare feeding the current concentrate (Dulce 20) being used with a DDGS concentrate. The feeding program at this ranch consists of offering an amount of commercial concentrate equivalent to 1 percent of body weight, where calves weighing an average of 100 kg receive 1 kg of concentrate and cattle weighing an average of 350 kg receive 3.5 kg of concentrate, when digestible forage is available in the grass pastures. This extra concentrate is known as "taco." A total of 32 bulls were divided into two groups with 16 bulls each and an average body weight of 112 kg, where Group 1 was fed DDGS and Group 2 was fed the current Dulce 20 concentrate. **Table 1** shows the initial number of animals and average body weight by group.

Table 1. Initial number of bulls and body weight used in the feeding trial

RANCHO LOS SIERRA, OZULUAMA VERACRUZ 24 FEBRERO 2017								
Group	CONTROL	SINIGA	kg		Group	CONTROL	SINIGA	kg
1	209	92	82		2	219		84
1	206	79	86		2	217		86
1	230		99		2	174	103	92
1	225	84	99		2	196	88	100
1	189	98	101		2	194	65	101
1	213	102	103		2	183	87	102
1	200	81	107		2	181	90	105
1	211	85	110		2	185	67	110
1	223	69	111		2	204	58	111
1	186	55	118		2	229	97	112
1	171	101	120		2	167		120
1	154	73	121		2	203	74	121
1	184	96	132		2	161	56	122
1	172	94	132		2	164	59	132
1	177	68	138		2	87	72	137
1	158	71	143		2	153	66	167
16		kg Total	1,802		16		kg Total	1,802
		kg average	112.6				kg average	112.6

The feeding trial began on February 24, 2017, when both groups were provided separate grass pastures with portable bunk feeders and ad libitum access to water. Every morning the animals received 2 kg of concentrate plus 1 kg of chopped hay, and the remainder of the day they had access to the grass pastures. At the end of each month the 32 cattle were moved to the holding pen to obtain body weights.

Initial body weight of both groups was 113 kg. At the end of the first month of the trial, the cattle in both groups had similar body weights (136 kg for those fed DDGS and 135 kg for those fed the commercial supplement). However, after feeding these concentrates for the second month, cattle fed the DDGS diet had greater body weight (152 kg), average daily gain (0.57 kg/day) and were projected to reach 230 kg in 138 days. The cattle in the control group had average body weight of 147 kg, average daily gain of 0.38 kg/day, and were projected to reach 230 kg in 218 days. However, growth rates were less than desired for both groups because of limited forage intake from the grass pastures during this time of the year. The cattle continued to be fed these same diets for the next month (May) and growth rates of the bulls did not improve from the previous month (0.58 kg/day for DDGS and 0.31 kg/day for control). After consulting with the owner, it was agreed to adopt a 100 percent confinement system and feed the cattle a diet consisting of 680 kg DDGS concentrate, 230 kg grass chopped hay and 90 kg of Sugarcane molasses. The bulls remained on the grass pastures, but it was recommended that they be fed 4 kg of the mixture per animal per day to improve nutrient intake and growth rate of these animals. Unfortunately, the cattle continued on the previous feeding program because the change in feeding program was not communicated to emplyees responsible for feeding the cattle. However, the final results showed a positive benefits of feeding the DDGS concentrate on body weight gains increased and days to reach 230 kg in body weight were reduced by 10 days. A summary of cattle body weights, body weight gain, and average daily gain are summarized in **Figure 1, 2 and 3**, respectively.

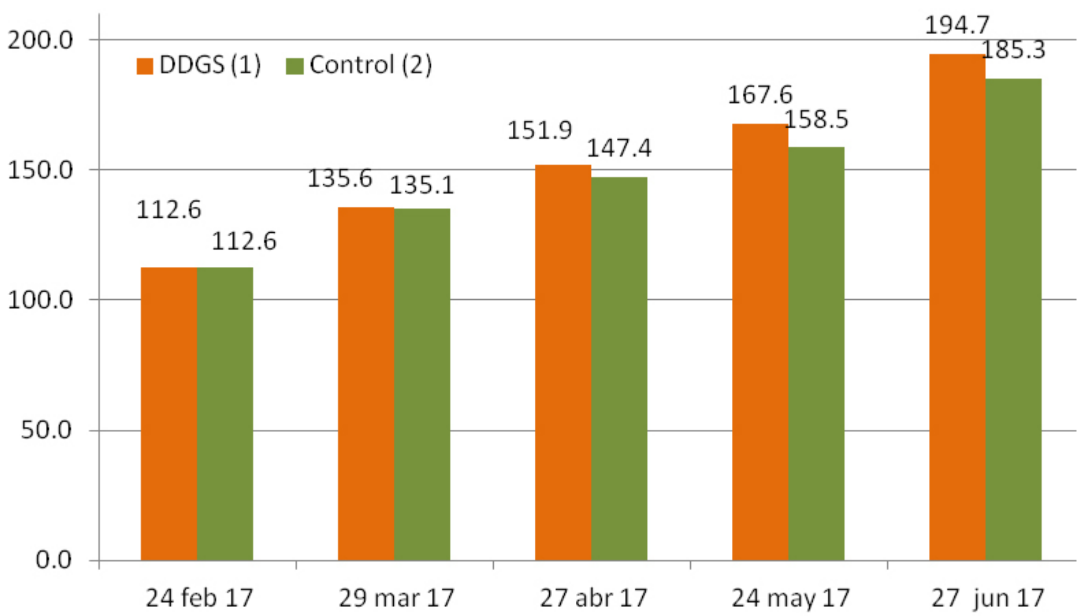


Figure 1. Comparison of average body weights of cattle fed DDGS vs control supplements over a five–month feeding period

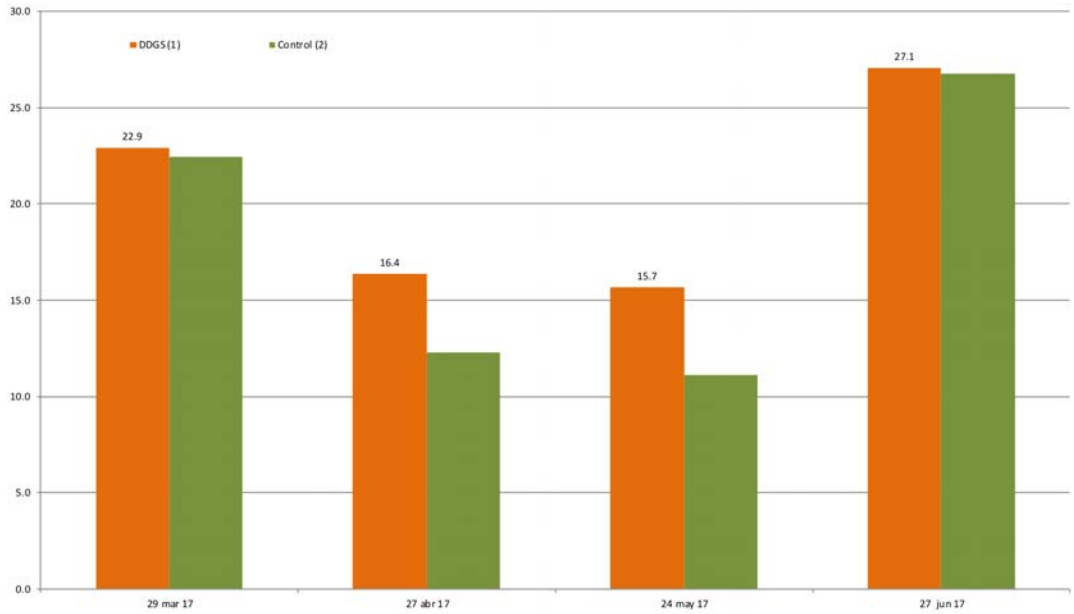


Figure 2. Comparison of average body weight gain of cattle fed DDGS vs control supplements over a five–month feeding period

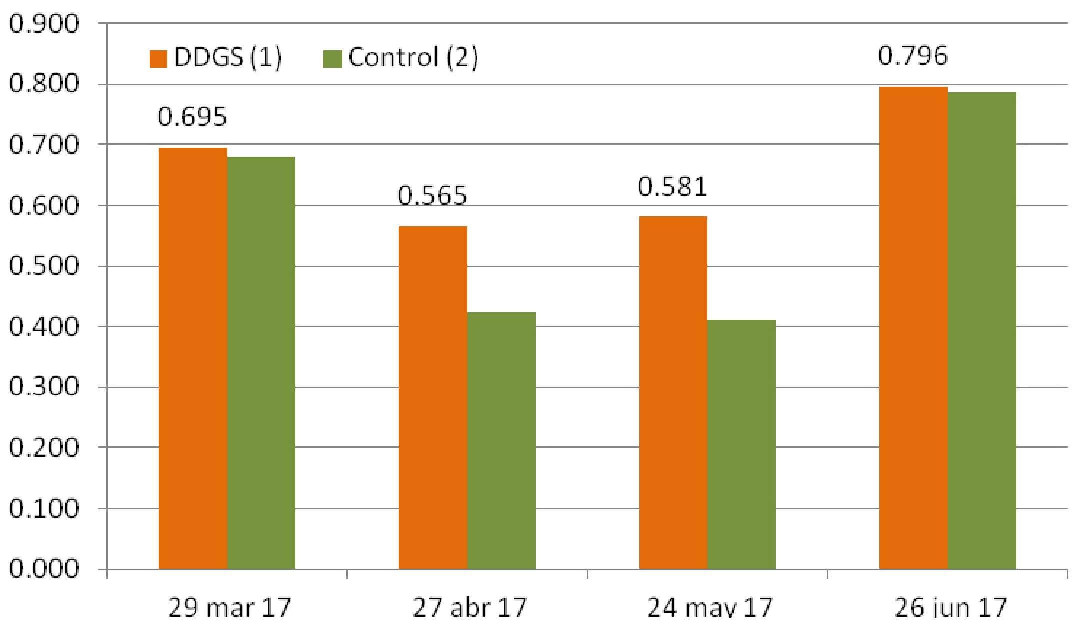


Figure 3. Comparison of average daily gain of cattle fed DDGS vs control supplements over a five–month feeding period

In this field demonstration trial, the same feeding practices were compared using with two types of concentrates, one with high levels of DDGS and a second one a commercial formula known as Dulce 20. The Dulce concentrate costs $8.00 Mx pesos/kg compared with $6.75 Mx pesos for the DDGS concentrate (**Table 2**). For these young bulls fed 3 kg of ration, which consist of 2 kg of concentrate and 1 kg of grass chopped hay, the cost of feeding the Dulce 20 Ration every day was $16.50 Mx pesos/animal compared with $14.00 Mx pesos/animal when feeding the DDGS ration.

After the 123 days feeding period, cattle fed the high DDGS concentrate had increased average daily gain and more kilogram gained during the period, which represents an important savings time and money. In addition, each animal from Group 1 (DDGS) generate a positive balance of $10.129 Mx pesos per day compared with the $4.010 Mx pesos from Group 2 (**Table 3**). Although the young bulls in this demonstration did not gain more than 0.80 kg per day compared with 1.3 kg per day from other demonstration trials in Mexico with the same weight, bulls fed the DDGS concentrated in this trial showed an economic benefit of about $1,000 Mx pesos per bull during the entire period of time compared with Group 2. In fact, the cost of kilogram gained was almost $8.2 Mx pesos per kilogram less compared with the cost from Group 2. In conclusion,

Table 2. Comparison of feed cost/animal/day when feeding a commercial concentrate or DDGS concentrate

Ration Dulce 20	kg /an / day	$ / kg	Cost
Concentrate	2	$8.00	$16.00
Chpped grass hay	1	$0.50	$0.50
Total cost	3		$16.50
		kg =	$5.50

Ration high DDGS	kg /an / day	$ / kg	Cost
Concentrate	2	$6.75	$13.50
Chpped grass hay	1	$0.50	$0.50
Total cost	3		$14.00
		kg =	$4.67

Table 3. Cost comparison of feeding a commercial supplement or a high DDGS supplement for the Los Sierra Ranch

DAILY COSTS	DDGS Group 1	Commercial Group 2
Daily supplement kg / animal	3	3
Daily Gain kg	0.667	0.590
Bank Interest 10% yr	$1.470	$1.470
Paddock rent / grass	$4.250	$4.250
Supplement 3 kg / animal	$14.000	$16.500
Extras	$1.500	$1.500
Total	$21.220	$23.720
Gross income	$31.349	$27.730
Balance	$10.129	$4.010
Feeding days to target weight	176.0	199.0
Initial weight	112.6	112.6
Final weight	230.0	230.0
TOTAL INVESTED MONEY / PERIOD		
$/period interest bank	$259	$293
$/period paddock rent	$748	$846
$/period DDGS supplement	$2,464	$3,283
$/period extras	$264	$298
Total	$3,735	$4,720
$ purchasing / animal	$5,292	$5,292
Total invested money / period	$9,027	$10,012
Total income 230 kg X $47/kg	$10,810	$10,810
Diference	$1,783	$798
Money turn over / year	2.074	1.834
Net income / year	$3,697.1	$1,463.6
Cost / kg gained	$31.81	$40.20

the genetic background from the bulls on this ranch can support a greater average daily gains if the farmer decides not to limit feed intake and provides sufficient nutrition to meet their daily requirements.

TRIAL 5

A beef cattle feeding trial was conducted in 2016 on the San Francisco ranch near Tizimin, Yucatan. Yucatán´s cattle production is mostly in the municipalities located to the east part of Yucatán´s Peninsula (Tizimín, Buctzotz, Panaba, Sucila), and cattle production systems in the state are extensive. Animals graze on native or induced pastures. Generally, supplements are only used during the dry season to scarcely meet maintenance requirements of the animals. Poultry litter is the main component of these feeds. A great majority of ranchers consider supplementation as a cost and not as an investment. Therefore, on traditional Yucatán farms, the average daily gain of cattle is between 400 and 600 grams per day. Reproductive results of traditional breeding herds are also below the optimal performance expected for this area and breeds. In general, Yucatán ranchers are conservative and rarely change their production practices, despite their poor results. However, farmers tend to look at one another to decide what to buy. They feel safe and reassured if another rancher buys a new product, particularly, if the buyer is leader of opinion among cattle producers.

Mr. Pedro Couoh is a well-known rancher among Yucatán producers, both for his excellent purebred Swiss herd and F1 crosses. Therefore, a feed demonstration at Mr. Pedro Couoh´s ranch (*San Francisco*) was conducted. Due to results the trial will have a positive impact on other regional cattle producers. In addition, the DDGS group will participate at Xtmakuil Livestock Fair, one of the most important Cattle Shows southeast Mexico.

Ranch Description:
Rancho San Francisco is located in the municipality of Tizimín, Yucatán The climate of the region is tropical sub-humid with monthly temperature and annual rainfall averages of 26 C and 1100 mm respectively. The ranch produces purebred Brown Swiss and F1 hybrid cattle.

Couoh uses a semi-intensive method of rearing. At night, animals graze on Mulato – 2 (*Brachiaria ruziziensis*), Brizantha (*Brachiaria brizantha*) and Tanzania (*Panicum maximum*) grasses and during the day, when temperatures tends to rise, animals are kept in free stall barns, where they are supplemented and have access to fresh water.

Facilities are well maintained and clean. The ranch has a digital scale to weigh the cattle. Unlike other ranches of the region, production records are kept. The ranch follows a preventive veterinary health program specific for this region.

Material And Methods:
Twenty-four Brown Swiss (BS) purebred and crossbred animals were assigned to two treatment groups (DDGS and control) to evaluate the effect of DDGS on the rate of gain of the cattle. Each group consisted of six bulls and six heifers. Initial body weights of the DDGS and of the control groups were 305 and 297 kg, respectively. DDGS group final weight was 366 kg, while final weight of the control group was 348 kg. The animals were weighted individually each 15 days. Eartags were used to identify each animal and keep accurate records for average daily gain (ADG). Trial duration was 75 days from July to October 2016.

The animals received two different diets. The control diet consisted of 3 kg commercial feed (16 percent crude protein content) and 3 kg of a mix of 70 percent poultry litter and 30 percent corn ("*Productor Plus*") per head per day (**Table 1**). The DDGS diet consisted of 3 kg supplement (85.47 percent DDGS/12.82 percent molasses/ 1.71 percent mineral premix) and 3 kg *Productor Plus* per head per day (**Table 2**). Total feed cost per head for the 75 day trial was Mx $1946.45 and Mx $1991.25, for the DDGS group and for the Control group, respectively. **Table 3** shows DDGS supplement composition. The poultry litter mixture composition is shown in **Table 4**. Each group was supplemented separately during the day and at night both groups grazed on Mulato – 2 (*Brachiaria ruziziensis*), Brizantha (*Brachiaria brizantha)* and Tanzania (*Panicum maximum*) grasses.

Results:
Because each 15 days animals were weighed, performance results are presented according to the five periods in which the trial was divided (five weighing dates). ADG is presented for each of these periods as well the accumulated ADG of the whole trial and by also by sex. The overall ADG for the DDGS group was greater 1 kg greater than that of the control group (0.84 kg). Nevertheless, rate of gain was not uniform, but both groups showed similar tendency (**Figure 1**), except at the fourth period, when the rate of gain of the DDGS animals presented a light decrease, but it recovered in the following period, but not for the control group, which ADG markedly decreased at the end of the trial. Compared ADG of both groups is presented in **Figure 2**.

ADG of bulls in the DDGS treatment was 1.42 kg/day, whereas ADG of bulls of the control group was 1.07 kg/day. In both cases, performance was not uniform. Over the entire trial, ADG of the DDGS group shows two decreases (second and fourth), but it markedly increased at the end of the trial. The control group showed similar tendency (**Figure 3**), except in the last two periods, when ADG substantially decreased. The ADG of both groups is presented in **Figure 4**.

Table 1. Control diet

Ingredient	Cost/kg Mx	kg/head/day	Cost/day, Mx
Commercial feed 16%	$6.10	3.0	$18.30
Productor Plus	$2.75	3.0	$ 8.25

Table 2. DDGS diet

Ingredient	Cost/kg Mx	kg/head/day	Cost/day Mx
DDGS supplement	$5.90	3.0	$17.70
Productor Plus	$2.75	3.0	$ 8.25

Table 3. DDGS supplement formula

Ingredient	percent
DDGS	85.47
Molasses	12.82
Mineral premix	1.71
Total	100

Table 4. Poultry litter mixture (Productor Plus)

Ingredient	percent
Poultry litter	70
Corn	30
Total	100

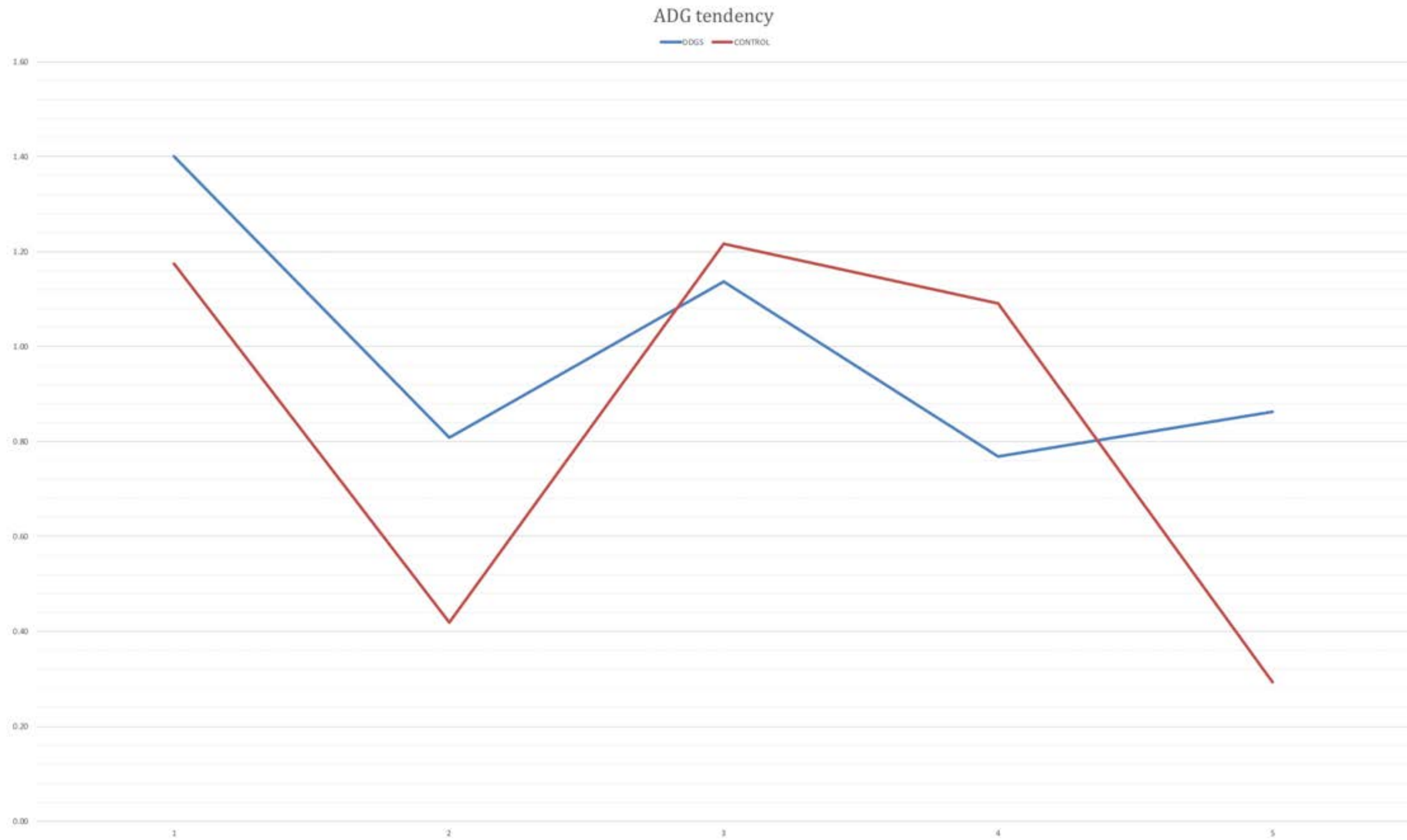


Figure 1. Variation in ADG of cattle fed the control and DDGS and Productor Plus during the trial

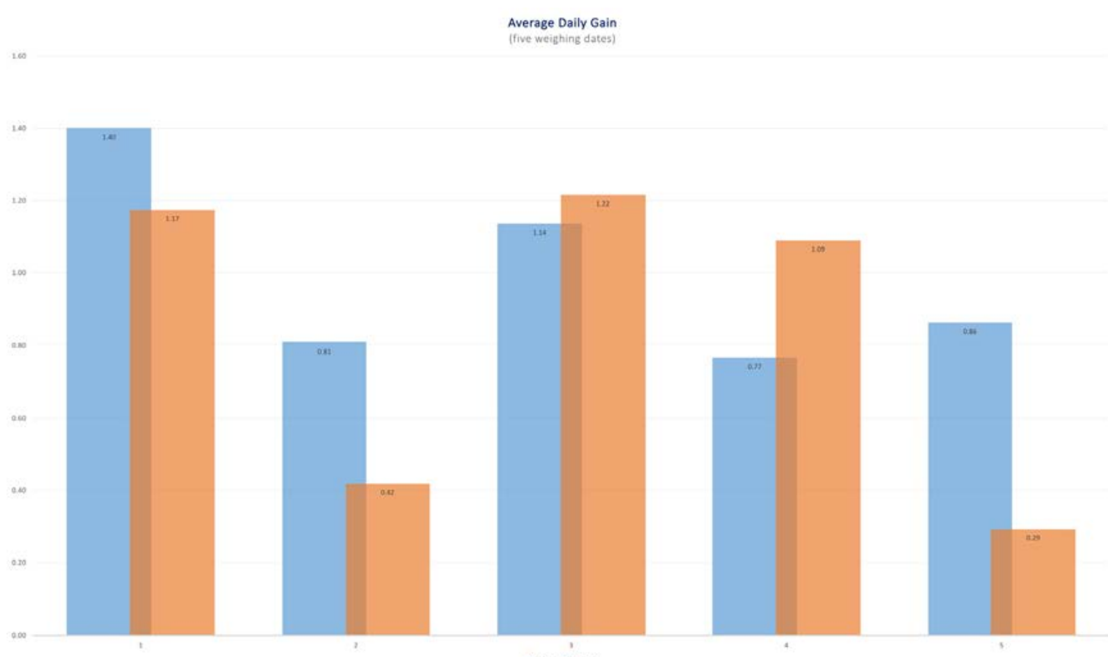


Figure 2. Average daily gain of both groups at various times during the entire trial

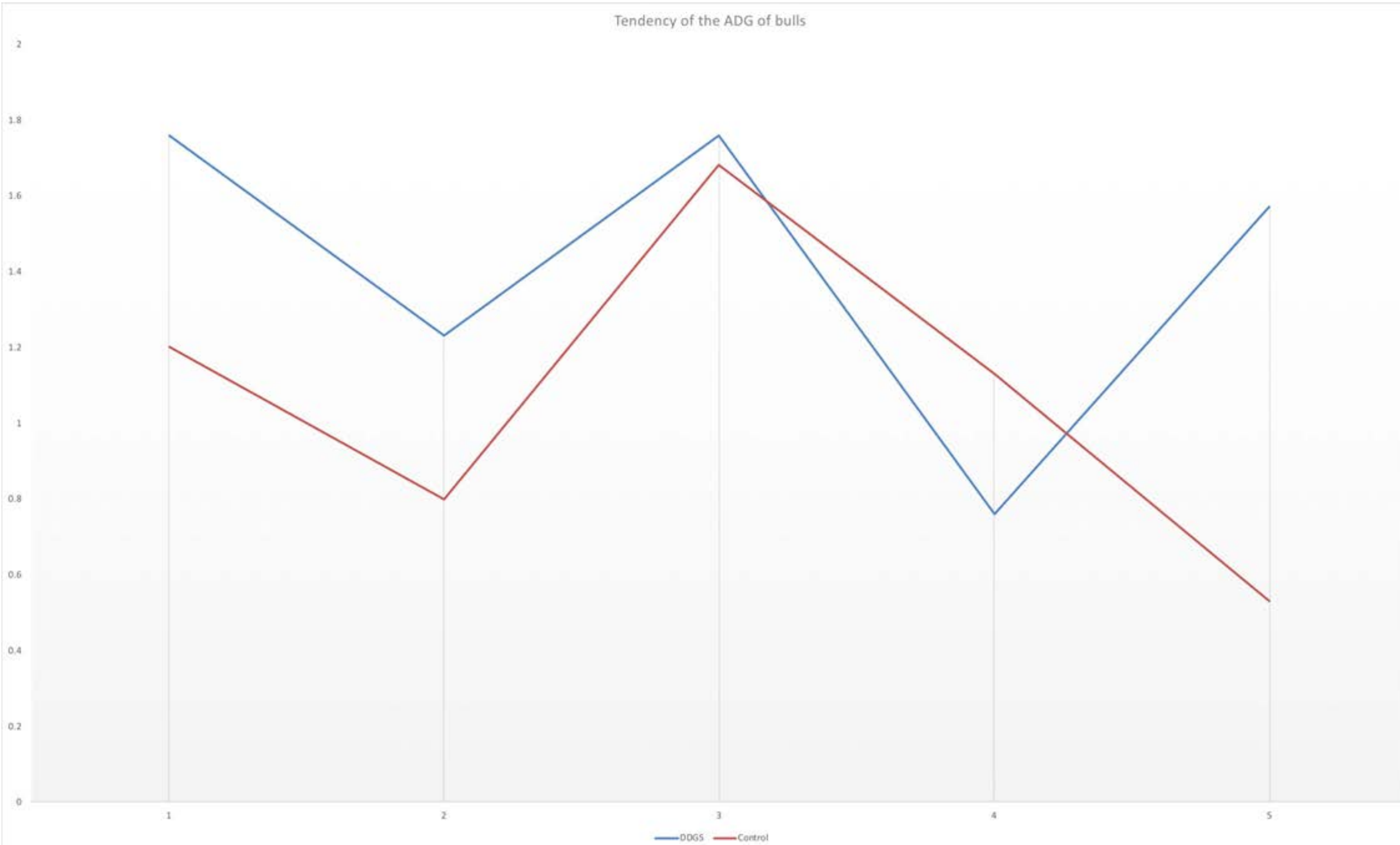


Figure 3. Variation in ADG of cattle fed the control and DDGS and Productor Plus during the trial

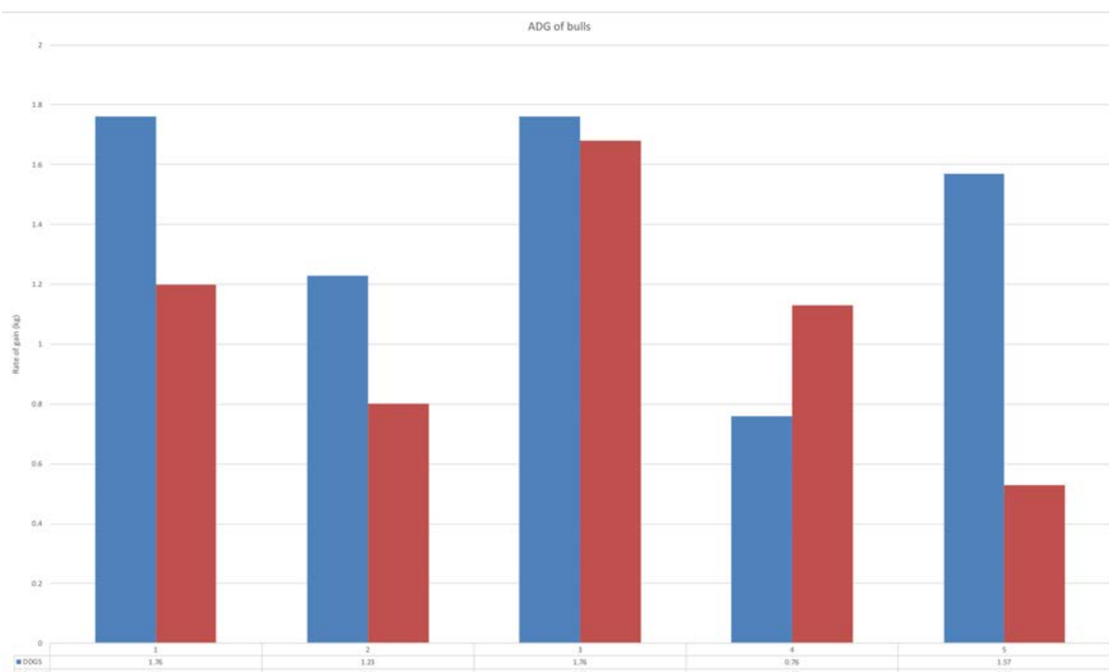


Figure 4. ADG of bulls of both groups

Accumulated ADG of heifers of the DDGS treatment was 1.08 kg/day, whereas ADG of heifers of the control group was 1.02 kg/day. In both cases, performance was not uniform over the trial, where ADG of the DDGS group shows two decreases (second and fourth), but it markedly increased at the end of the trial. The control group showed similar tendency, except in the last two periods, when ADG substantially decreased. ADG of both groups is presented in **Figure 5**.

Bull fertility test

Because these animals will be sold for breeding, performing a fertility test prior to sale was important to guarantee customers the fertility of the bulls as potential breeders. Examination of internal and external genitalia, as well as collection and evaluation of semen of all males was performed. Both group of animals presented normal genitalia, and results of the qualitative and quantitative evaluation of semen were also normal.

Animal coat and general appearance of the animals

The owner commented that the coat and general appearance of the animals of the DDGS group was better than the Control group.

Economic Analysis

The cost per kilogram of body weight gain was calculated considering total feeding costs for the entire trial, as well as body weight increase of both groups. In the case of the DDGS group, the cost per kilogram of body weight gain, was Mx $31.91, or 18 percent less than the control group, which cost had a cost of Mx $39.04/kg body weight gain (**Table 5**).

Conclusions

1. The ADG of animals receiving a diet with DDGS was greater than the ADG of the control group that were fed a common commercial supplement.

2. DDGS can be effectively used to feed animals raised under extensive and semi-intensive systems, under Yucatán´s climatic conditions.

3. DDGS is a cost effective ingredient for typical cattle diets, used in Yucatán.

4. Feeding DDGS does not affect fertility of young bulls.

5. Feeding DDGS appears to improve cattle hair coat.

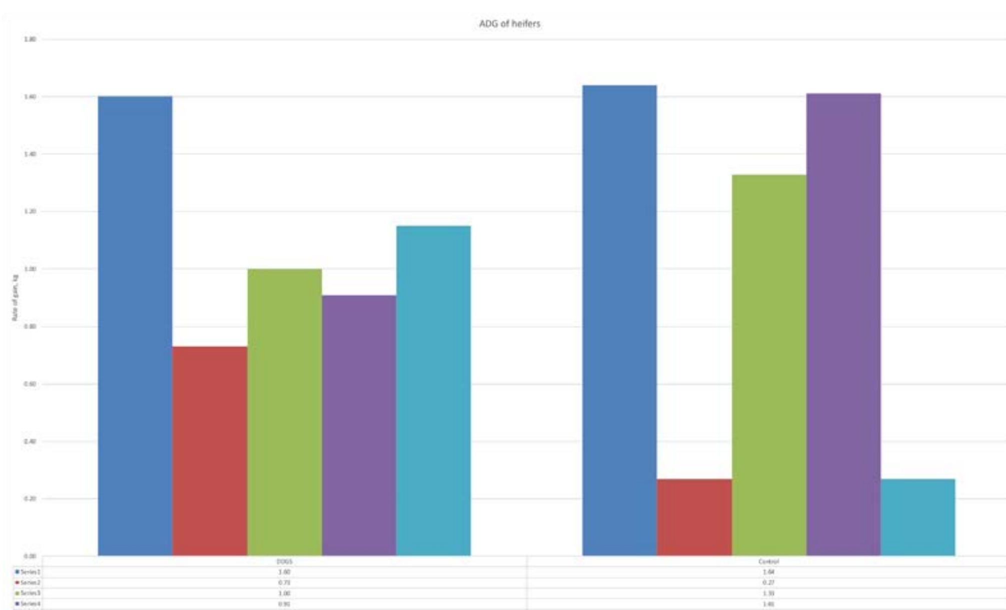


Figure 5. Average daily gain of heifers in both dietary treatment groups
Note: each series corresponds to a weighing period.

Table 5. Cost/kg of body weight gain	DDGS	Control
Initial weight, kg	305	297
Final weight, kg	366	348
Difference, kg	61	51
Total feed cost/trial	$1,946.45	$1,991.25
Cost/kg gained	$ 31.91	$ 39.04

Dairy Cattle

TRIAL 1

A lactating dairy cow feeding trial was conducted in Francisco Gaytan, Huimanguillo Tabasco, Mexico to compare milk production among two groups of cows with similar days in milk and milk production. A total of 34 cows (less than 105 days in lactation) were used and allotted to one of two feeding groups where they were fed 2 kg/cow/day of either a regular commercial concentrate (n = 17 cows) and the second group was fed a DDGS supplement (n = 17 cows). The supplement formulation is shown in **Table 4**. The supplement formulation is shown in **Table 1**. According to the information provided by the owner, the cost of the commercial concentrate was $5.00 Mx pesos/kg and the DDGS supplement was $5.76 Mx pesos/kg. The milk produced was delivered to a local cheese plant and the price paid was $5.20 Mx pesos/liter, and the milk was tested individually every 14 days.

Results from this trial are shown in **Figure 1 and 2**. Cows fed the DDGS supplement and were less than 50 days in milk (DIM) produced 2.88 more liters/day of milk than cows fed the commercial supplement (**Figure 1**). These results suggest that greater improvements in milk production may be achieved by feeding the DDGS supplement when cows reach peak milk production. As shown in **Figure 5**, cows fed the DDGS supplement produced 2.77 more liters of milk, and this increase became greater by the end of the feeding trial.

Table 1. DDGS supplement formulation

Ingredient	kg / MT
Grass hay	100.0
DDGS	559.2
Sugarcane molasses	111.4
Ground yellow corn	155.9
Urea	17.8
Mineral Premix	55.7
Total	1,000.0

The higher cost of the DDGS supplement is often not accepted by most milk producers in Mexico because they want to buy inexpensive concentrates that produce a lot of milk. During this demonstration it was evident that the commercial concentrates do not support a higher milk production, which limits the potential milk production. As shown in **Table 2**, cows fed the DDGS supplement had $1.52 greater feed cost/day than those fed the commercial supplement. However, as shown in **Table 3**, cows fed the DDGS supplement produced more milk which resulted in greater gross and net income than cows fed the commercial supplement. These results convinced the owner that even though the DDGS supplement was higher in cost, it also resulted in greater milk production. As a result, the owner has decided to start producing and selling the supplement in her town.

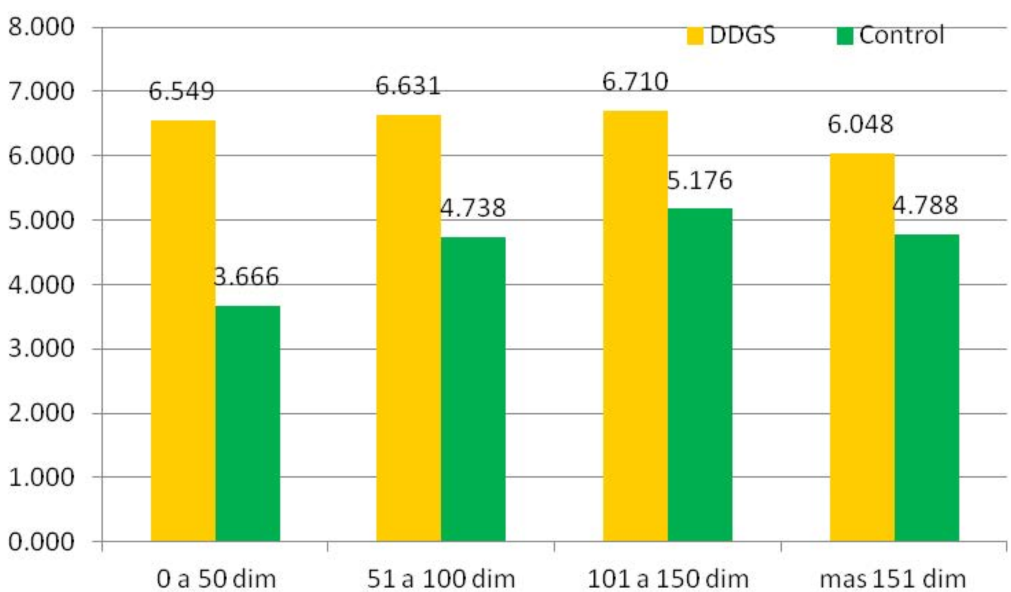


Figure 1. Average milk production (liters) by days in milk

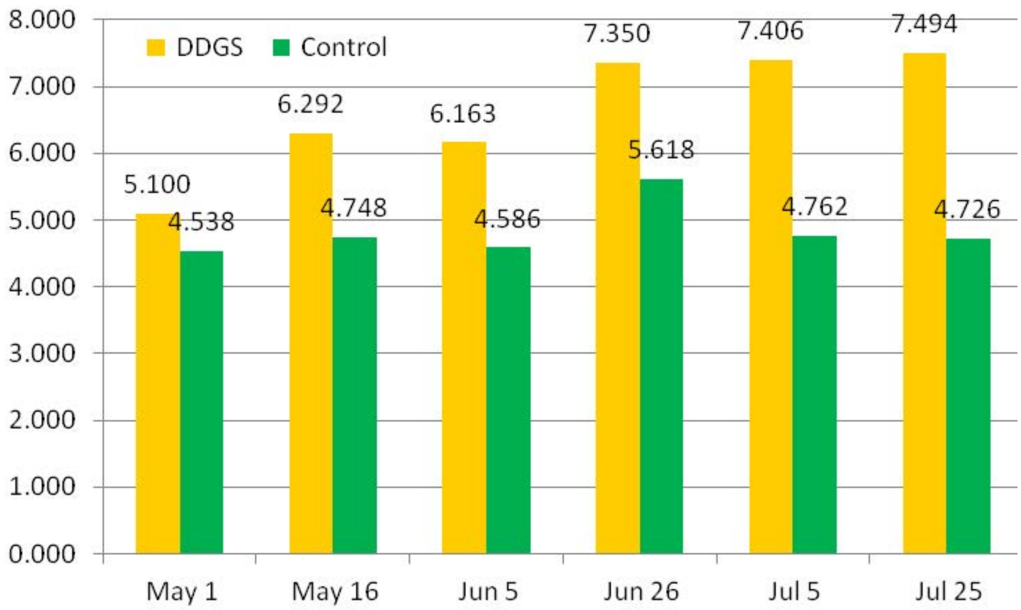


Figure 2. Average milk production (liters) for the entire feeding trial

Table 2. Comparison of commercial and DDGS supplement cost per cow per day

Supplement	Concentrate/cow per day, kg	$ Mx pesos/kg concentrate	pesos/cow/day
DDGS	2	$5.76	$11.52
Commercial	2	$5.00	$10.00
Difference	-	$0.76	$1.52

Table 3. Comparison of gross and net income from feeding the commercial and DDGS supplements per cow per day

Supplement	Milk/cow/day, liters	Mx pesos/liter	Gross income Mx pesos
DDGS	7.494	$5.20	$38.97
Commercial	4.726	$5.20	$24.58
Difference			$14.39

Recent Demonstration Trials in Vietnam

Dairy Cattle

Effect of feeding corn corn DDGS on milk production under hot climate conditions in Vietnam

ABSTRACT

A feeding trial on US corn DDGS was conducted at commercial dairy farm during hot condition in Vietnam in 2010. One hundred and fifty six dairy cows in later stage of milk production were allotted randomly in three groups to contain 52 cows with similar milk production. Three dietary treatments comprised 1. Control diet, 2. Diet with 7.5 percent DDGS and 3. Diet with 15 percent DDGS. The diets were formulated to contain similar nutrient profile and comprised forages (corn, elephant grass and alfalfa hay), brewery waste, soybean curd waste, corn, soybean meal, molasses and commercial dairy supplement. The diet was manufactured locally in total mixed ration system and the diet was delivered two times per day. Milk production, feed consumption and milk quality was measured five days before the trial and 45 days after trial. Result demonstrated that feeding DDGS would support higher milk production without affecting feed consumption. Feeding DDGS at 7.5 percent and 15 percent resulted in higher milk production at 2 and 4 kg/day respectively compare to cows fed control diet. Feed intake remained unaffected at around 35 kg/day. Milk quality as measured by total solid and fat content was similar between cows fed control diet and DDGS at 7.5 percent. Feeding DDGS at 15 percent tend to have slightly better total solid and fat content. Feeding DDGS was able to reduce cost of the diets; diet cost for control, DDGS 7.5 percent and DDGS 15 percent were VND/kg 2537, 2460 and 2399, respectively.

INTRODUCTION

DDGS is a by-product of ethanol industry from fermentation of corn and has used for animal feeding. Increase of ethanol production in the U.S. for the last 10 years has resulted in a higher amount of DDGS becoming available for animal feed. It was estimated that 30 million tons of DDGS was produced in 2009 and 4.5 million tons was exported to different countries around the world.

Research on feeding DDGS for dairy has been conducted in many universities for the last 20 years. Based on 23 studies investigating the inclusion of DDGS in dairy cow diets with 96 treatment comparisons, Kalscheur (2005) conducted a meta analyses and reported that in general, DDGS is considered are considered to be highly palatable and stimulated feed intake when DDGS are included up to 20 percent of the dry matter in dairy cow diets. Milk production was not impacted by the form of DDGS fed, but there was a curvilinear response to increasing DDGS in dairy cow diets. Cows fed diets containing 4 to 30 percent DDGS produced the same amount of milk, approximately 0.4 kg/d more, than cows fed diets containing no DDGS. When cows were fed the highest inclusion rate (more than 30 percent) of DDGS, milk yield tended to decrease. It is recognized that DDGS quality has changed over this time period.

In the U.S., initially DDGS is fed in wet form without drying to the cattle raised in proximity to the ethanol plant. Increasing numbers of modern ethanol plant have resulted in more DDGS being produced in dried form. Feeding trials of DDGS conducted in the U.S. using DDGS derived from the older technology has darker color. Power et al. (1995) reported that feeding darker color of DDGS resulted in a lower milk production compared to DDGS in lighter color.

DDGS is a very good protein source for dairy cows. According to Schingoethe (2004), the protein content in high quality DDGS is typically more than 30 percent on a dry matter and DDGS contains 10 percent fat. DDGS is a good source of ruminally undegradable protein (RUP), or by-pass protein and the content was 55 percent. DDGS is also a very good energy source for dairy cattle with Total Digestible Nutrient (TDN) value 77 percent, NE_{gain} 1.41 Mkal/kg, and $NE_{lactation}$ 2.26 Mkal/kg. This new energy value of DDGS is reported 10 to 15 percent higher than that reported by NRC (2001).

Most of the DDGS research involving dairy cattle has been conducted in temperate climates. Chen and Shurson (2004) reported from field feeding trials of DDGS to dairy cows conducted during summer period in Taiwan that inclusion of DDGS 10 percent in total mix ration (TMR) was able to increase milk production at 0.9 kg/day without affecting feed intake. DDGS can also be fed to growing heifers, but the trial was limited; Kalscheur and Garcia (2004) reported that DDGS could be fed to heifers up to 40 percent in the rations.

The dairy industry in Vietnam is majority located in the south tropical areas and expanded to the central and north. The summer period in the north will be critical in feeding dairy as the feed consumption decreases significantly and DDGS can be valuable feed ingredient for dairy cattle. Vietnam has been importing DDGS from the U.S. from the last four years, but mainly used for swine and poultry feed and lately on fish feed. Currently no DDGS has been used for feeding dairy cattle despite 250.000 head of dairy cattle in Vietnam. Dairy production increased significantly in the last five years and it was predicted that dairy production will increase greater than 10 percent annually. Potential of DDGS for dairy cattle is significant, it was estimated that if 1 kg of DDGS can be fed to cattle every day, Vietnam may require 250.000 metric tons of DDGS per year. Vietnam has been importing DDGS from the U.S. from the last four years, but mainly used for swine and poultry feed.

Dairy cattle is normally fed green roughage and supplemented by a concentrate comprised industrial by products such as soybean meal, wheat bran, rice bran, cassava waste, cassava, molasses, and mineral/vitamin mix. However, the use of DDGS in Vietnam is not known and it would be useful information if a feeding trial of DDGS can be conducted specific to dairy cattle in Vietnam.

MATERIALS AND METHODS

Feeding trial was carried out at commercial dairy farm of PHU LAM, Tuyen Quang, Vietnam.

Feeding trial comprise three dietary treatments:

A. Control diet without DDGS in the form of total mixed ration

B. Diet contained 7.5 percent DDGS in the form of total mixed ration

C. Diet contained 15 percent DDGS in the form of total mixed ration

The feeding trial was conducted in randomized complete design using three groups of dairy cows in similar milk production and each group of cows was placed in pen to contained 52 dairy collected randomly from population of cows available in the farm. The cows were selected from the latest stage of milk production with average milking days greater than 200 days. Phu Lam Dairy Farm feedmlll in Tuyên Quang manufactured the dietary treatments according to formula met dairy requirement in TMR form. The feed was formulated similar in nutrient composition as presented in **Table 1**.

Each dietary treatment was fed to three groups of dairy cows placed in existing pen containing 52 cows per pen; therefore total 156 dairy cows were used. Each treatment was fed for 45 days and data on milk production from individual cow and feed consumption was collected five days prior to feeding and 45 days after feeding.

Feeding system

Feeding system was conducted according to the existing system at Phu Lam Dairy Farm Dairy farm. Total mixed ration comprised of roughage (Napier grass and corn forages) and mixed with other ingredients including cassava, soybean curd waste, brewery waste, ground corn, soybean meal, supplement from feedmlll (40 percent), molasses, solid fat and mineral-vitamin premixes. The least cost formulation was performed to provide sufficient nutrient to the cows need as suggested by NRC (2001). Cows were fed 2 times daily and feed refuse was weighed daily. Amount of feed was calculated based on the cows and milk production.

Measurement

Measurement was conducted for daily milk production, feed intake and milk quality comprises protein, fat, total solid and density. For milk quality, five samples was collected for each dietary treatment at mid and end of trial, therefore total 15x2 = 30 samples of milk was analyzed.

Statistical analyses

Data collected were analyzed for using Proc. GLM of SAS program and any significant different was further analyzed by Duncan test (SAS ver. 6.12).

RESULTS AND DISCUSSION

Environmental conditions

Average daily temperature and relative humidity of animal house during May to June 2010 when the feeding DDGS was performed is presented in **Table 2**. These months are well known as the hottest months of the year in northern part of Hanoi, Vietnam. The temperature reached maximum at 37°C or 99°F with humidity reached 88 percent. The animal house is open and supported by fan only.

Milk production and feed consumption

Average feed intake and milk production of cows before and after feeding different level of DDGS is presented in **Table 3**.

Milk production of cows before feeding DDGS is higher than cows after feeding DDGS as the trial was performed at later stage of milk production, therefore milk production decreased with continue feeding. The difference in milk production before and after feeding indicated the effect of dietary treatment on milk production. **Table 3** shows that difference in milk production is more pronounce in cow fed control diet compare to cow fed DDGS. The cow fed diet containing 7.5 percent DDGS has the milk production difference 4.0 kg/day while the control treatment resulted in 6.1 kg/day difference. Higher feeding of DDGS at 15 percent in the diet resulted in the difference in milk production only 2.1 kg/day. Feeding DDGS significantly resulted in higher milk production compare to the control diet.

Daily milk production of cow fed different level of DDGS is presented in **Figure 1**. All cows' milk production is in declining stage as they were in later day milk production. **Figure 1** indicated clearly that milk production from the control diet declined in much faster rate than cows fed DDGS 7.5 percent and the least decline was found in cows fed DDGS 15 percent in the total mixed ration.

Results of this trial shows clearly that feeding DDGS is able to maintain higher milk production during hot temperatures in Vietnam. Feeding DDGS at 15 percent in the total mixed ration was able to produce 4 kg more milk compare to cows fed control diets. This result was in agreement with

Table 1. Dietary formula of Total Mixed Ration containing DDGS at 0, 7.5 percent and 15 percent for feeding dairy cattle at Vinamilk, Tuyen Quang			
Ingredients	**Control**	**DDGS 7.5 percent**	**DDGS 15 percent**
Corn silage	29.40	29.40	29.40
Elephant grass	28.01	29.40	29.40
Alfalfa hay 22	9.80	5.91	5.00
Brewery dried grains	7.35	7.35	7.35
Soybean curd waste	7.35	7.35	4.51
Corn, ground	6.00	1.80	
Molasses	4.90	4.10	4.90
Dairy concentrate 40% (guyomarch)	3.40	3.40	3.40
Soybean meal	2.75	2.75	
Solid fat (bergafat)	0.39	0.39	0.39
Di calcium phosphate	0.30	0.30	0.30
Sodium bicarbonate	0.30	0.30	0.30
Vitamin + mineral premixes	0.05	0.05	0.05
DDGS %		7.50	15.00
Calculated nutrient content based on dry matter			
Moisture %	51.7	52.8	53.0
Total digestible nutrient %	70.6	72.0	72.7
Net energy lactation (mcal/kg)	1.72	1.76	1.78
Crude protein %	15.1	17.1	17.0
Neutral detergent fifer %	29.8	33.3	38.6
Acid detergent fiber %	18.3	19.1	20.6
Calcium %	1.02	0.91	0.87
Phosphorus %	0.45	0.51	0.54
Sodium %	0.27	0.29	0.32
Magnesium %	0.21	0.20	0.20
Sulfur %	0.18	0.19	0.21
Udp %	8.6	9.7	9.3
Rup %	6.8	7.4	7.8
Cost (VND/kg)	**2537**	**2460**	**2399**

Table 2. Temperature and relative humidity of animal house during feeding trial on DDGS		
	Temperature (°C)	**Relative Humidity (%)**
Minimum	28	74
Maximum	37	88
Average	33	82

the feeding DDGS during summer period in Taiwan that feeding DDGS at 10 percent in the diet was able to increase milk production at 1 kg/day (Chen and Shurson, 2004). The current trial in Vietnam showed a better production yield compare to the trial conducted in Taiwan.

Table 3 shows that average daily feed consumption is not affected by dietary treatment. Daily feed consumption of cows fed control diet is 35.6 kg while cows fed 7.5 percent and 15 percent DDGS is 35.3 and 35.6 kg respectively. There is also no difference in feed consumption of cows before feeding trial was started. DDGS diet was readily consumed by cows within few days of adaptation. Feeding DDGS was able to reduce cost of feed, **Table 1** indicates that diet cost for control, DDGS 7.5 percent and DDGS 15 percent were VND/kg 2537, 2460 and 2399, respectively. It is calculated that every inclusion of 10 percent DDGS in the dairy cows diet, the cost of feed will decrease VND 95/kg or around four percent.

Fluctuation in daily feed intake was noticed during feeding trial and the data is presented in **Figure 2**. It was noticed that there is no difference in feed consumption between dietary treatments. The feed intake fluctuation was related with the temperature and humidity of the house during the day. When the temperature increased and humidity was high, the cows tended to reduce feed intake while feed consumption was higher at lower temperature.

Milk quality

Milk quality was measured based on total solid and fat content and the result of measurement of milk quality before and after feeding DDGS is presented in **Table 4**. Total solid and fat content of milk from cow fed 7.5 percent DDGS was not different with that milk from cows fed control diet. There is slightly higher total solid and fat content when cows fed 15 percent DDGS in the ration. These results indicate that feeding 15 percent DDGS improved milk quality compared with milk quality before DDGS was fed.

Table 3. Average milk production and feed consumption of cows before (5 days) and after (45 days) feeding DDGS at different level under hot climate condition

Treatment	Milk Production (kg/day)		Difference (kg/day)	Feed Consumption (kg/day)	
	Before DDGS	After DDGS		Before DDGS	After DDGS
Control	20.5	14.4[a*]	6.1	36.8	35.6
DDGS 7.5%	19.2	15.2[ab]	4.0	38.3	35.3
DDGS 15%	18.2	16.1[b]	2.1	36.8	35.6

* Different superscript in the same column indicate significant different (P less than 0.05) and at Standard Error Means (SEM) 0.4 kg/day

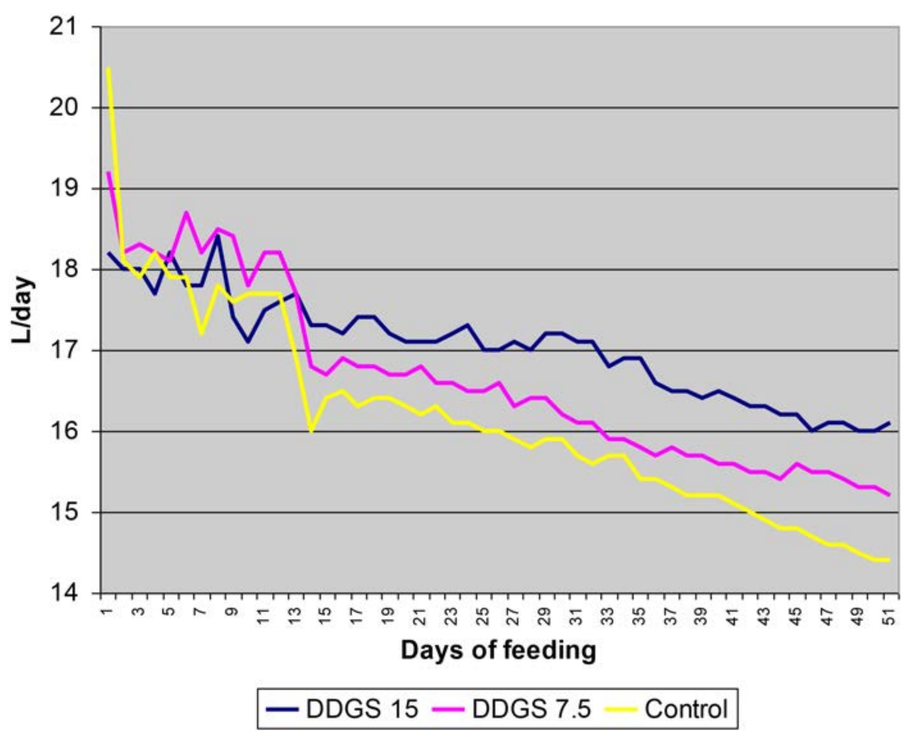


Figure 1. Daily milk production of cows fed different level of DDGS under hot condition in Vietnam

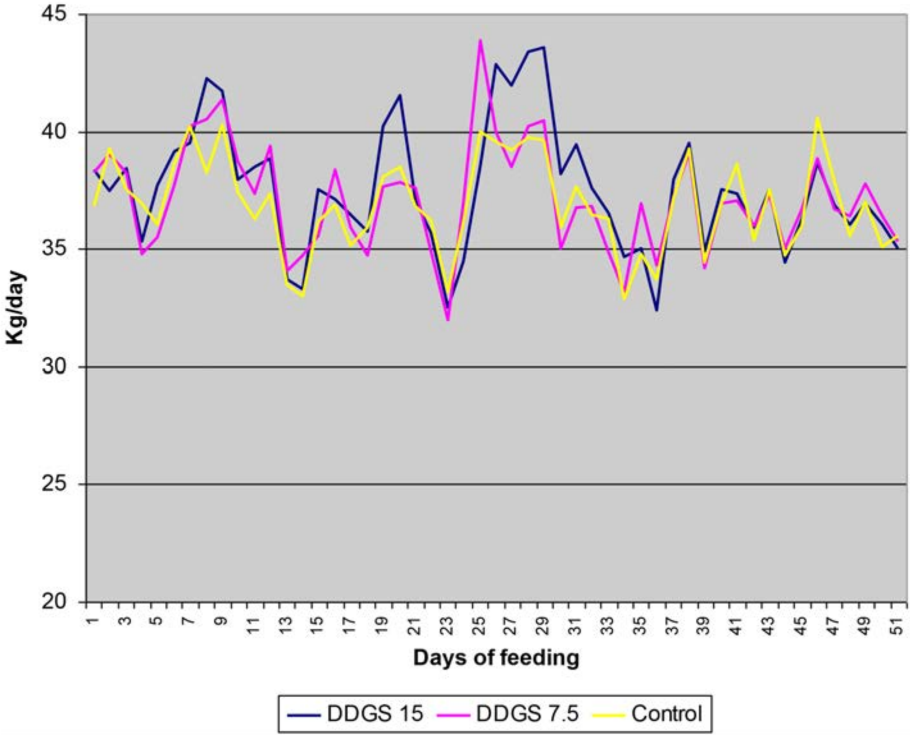


Figure 2. Daily feed consumption (kg/day) of cows fed different level of DDGS under hot condition in Vietnam

Table 4. Total solid and fat content of milk from dairy cow before and after feeding DDGS at different level under hot climate condition

Treatment	Total Solid (%)		Difference (%)	Fat Content (%)		Difference (%)
	Before feed	After feed		Before feed	After feed	
Control	12.5	12.1	-0.4	3.8	3.7	-0.1
DDGS 7.5%	12.4	12.1	-0.3	3.8	3.7	-0.1
DDGS 15%	12.0	12.4	0.4	3.6	4.0	0.4

CONCLUSIONS

1. Diets containing DDGS is readily consumed by dairy cows.

2. Feeding DDGS was able to improve milk yield of cow raised under hot climate condition.

3. Diet containing 15 percent DDGS was able to maintain the production and resulted in 4 kg higher compare to control diet, while diet containing 7.5 percent DDGS resulted in 2 kg higher.

4. Milk quality from cow fed 15 percent DDGS was tend to be better compare to that cow fed 7.5 percent and control diet.

ACKNOWLEDGEMENT

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REFERENCES

Chen, Yuan-Kuo and J. Shurson. 2004. Evaluation of distiller's dried grains with solubles for lactating cows in Taiwan. http://www.ddgs.umn.edu/international-translations/Taiwanese (Yuan-Kuo Chen 2004).pdf

Cyriac, J., M. M. Abdelqader, K. F. Kalscheur, A. R. Hippen, and D. J. Schingoethe. 2005. Effect of replacing forage fiber with non-forage fiber in lactating dairy cow diets. J. Animal Sci. 88(Suppl. 1):252

Kalscheur, K. F. Impact of feeding distillers grains on milk fat, protein, and yield. Distillers Grains Technology Council. 9th Annual Symposium. Louisville, KY. May 18, 2005.

Kalscheur, K.F. and A.D. Garcia. 2004. Use of by-products in growing dairy heifer diets. Extension Extra, South Dakota State University. ExEx 4030, 3 pp.

National Research Council. 1981. Nutrient Requirements of Dairy Cattle. 5th Rev. Ed. National Academy of Sci., Washington, DC.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. 7th Rev. Ed. National Academy of Sci., Washington, DC.

Powers, W.J., H.H. Van Horn, B. Harris, Jr., and C.J. Wilcox. 1995. Effects of variable sources of distillers grains plus solubles on milk yield and composition. J. Dairy Sci. 78:388-396.

Schingoethe, D.J. 2004. Corn Co products for Cattle. Proceedings from 40th Eastern Nutrition Conference, May 11-12, Ottawa, ON, Canada. pp 30-47.

USGC, 2007. Handbook of DDGS. U.S. Grains Council, Washington DC.

Aquaculture

Effect of feeding DDGS to growth performance and fillet color of *Pangasius*

ABSTRACT

A feeding trial on corn DDGS was conducted to *Pangasius* catfish at the research farm of a private company in Vietnam in 2015. DDGS was obtained from the U.S. and was analyzed for chemical composition and amino acids content. Six thousand *Pangasius* fingerling at 40 g body weight were allotted randomly in 16 floating cages made of nylon net placed in 0.5 hectare pond at 3 m deep. The cages were divided into four groups of dietary treatments and replicated four times. Four dietary treatments were used DDGS 0 percent, DDGS 5 percent, DDGS 10 percent and DDGS 15 percent containing 0, 50, 100 and 150 g g/kg of DDGS in the diets respectively. The diets were formulated to have same nutrient content using soybean meal, rice bran, cassava, fish meal, wheat and wheat bran. The fish was fed starter diet and continued with grower diets containing 280 g g/kg and 260 g g/kg respectively in floating form. The feeing trial was performed for 118 days but fish sampling was conducted after feeding 42 and 78 days. The diets containing DDGS were consumed readily by *Pangasius*. The results showed that there is no different on growth performance of *Pangasius* fed different levels of DDGS. Body weight of the fish fed DDGS 0 percent, 5 percent, 10 percent, 15 percent were 471, 472, 470 and 490 g, respectively, while gain:feed ratio were 1.59, 1.62, 1.56 and 1.53 respectively. There was no different in fish mortality due to dietary treatments. Fillet yield was improved slightly by feeding DDGS, from 526 g g/kg in *Pangasius* fed no DDGS to 531 g g/kg fed 150 g g/kg DDGS. Fish fillet color measurement by color different meter showed that L, a and b values were not statistically different due to dietary treatments and prolonged feeding of DDGS up to six months did not show color values differences related with yellowness. In conclusion, corn DDGS can be successfully fed to *Pangasius* and feeding DDGS up to 150 g g/kg in the diet did not affect the fillet color.

INTRODUCTION

DDGS (Distiller Dried Grains with solubles) is a by-product of the ethanol industry and contains a mixture of distiller grains with solubles from fermentation of corn and it has used for animal feeding. Increase of ethanol production in U.S. for the last 15 years has resulted in a higher amount of DDGS become available for animal feed. It was estimated that greater than 40 million tonof DDGS is produced in 2014 and greater than 10 million tonis exported to different countries around the world (USGC, 2014). It has been shown to be economically feasible for animal feed especially in dairy cattle, swine and poultry.

Catfish is one of major fish grown in Vietnam and is considered popular species for human consumption locally. Catfish from Vietnam has been exported to many different countries in Europe, the U.S. and the Asia Pacific region. It is grown in a pond water or cage system in river areas in Mekong Delta Vietnam. Catfish is cultured until market size in the range of 500- 1000 g. Catfish feed is commonly made of several ingredients such as soybean meal, wheat by products, fish meal, rice by product, cassava etc.

Limited data was available on feeding value of DDGS as *Pangasius* catfish feed. DDGS has been fed successfully to channel catfish; Tidwell et al. (1990) conducted an experiment over an 11-week period where channel catfish fingerlings were fed diets containing 0 percent, 10 percent, 20 percent and 40 percent DDGS, replacing some of the corn and soybean meal. In 1993, Webster et al. conducted feeding study to juvenile catfish and suggested that up to 30 percent DDGS can be added to channel catfish diets with no negative effects on growth performance, carcass composition or flavor qualities of the filets. Therefore, DDGS is considered an acceptable ingredient in diets for channel catfish (Tidwell et al., 1990; Webster et al., 1991).

However the early DDGS trials were performed using DDGS manufactured by old technology, while ethanol production technologies have evolved to modern or new technologies by using advance fermentation including the use of selected enzymes, yeast and modern processes. Currently in the U.S. there are more than 200 ethanol plants established in the last 20 years and DDGS has a better quality and brighter yellow color. Earlier data indicated that new DDGS can be fed successfully to replace plant protein sources for tilapia (Coyle et al., 2004; Shelby et al., 2008) and channel catfish (Robinson and Li, 2008, Li et al., 2010, 2011, Zhou et al., 2010). Cheng and Hardy (2004) was able to use DDGS up to 15 percent in the diet of trout to replace fish meal and recent study by Overland et al., 2013 reported that DDGS could be included in rainbow trout diet up to 10 percent to replace other plant protein sources including sunflower meal, rapeseed meal and field peas.

Most of aquaculture production especially fresh water fishes are located in Asia and Vietnam is a leading country to produce catfish for local consumption and export. Vietnam catfish are slightly different from U.S. channel catfish, Vietnam catfish was originated from Mekong River and named *Pangasius hyphotalamus*. Vietnam catfish production continues to increase in the last few years and fillet of *Pangasius* has been exported to many different countries. However, many exporters demanding the fillet to be white in color as requested by consumers. There is a concern that feeding corn DDGS may result to the different color of fillet as the color substances from DDGS might be transferred to the fillet. This assumption has never been proved from the research except Webster et al., 1993 reported that feeding

DDGS did not affect fillet flavor quality. Therefore the purpose of the trial was to evaluate feeding value of DDGS and its effect to fillet color of *Pangasius*.

MATERIALS AND METHODS

A trial on growth performance was carried out at experimental farm of Hung Vuong Co., Mekong Delta Sadec, Vietnam while feed production for the trial was performed at Hung Vuong feedmlll. Fish culture was performed in 16 floating cages at size 4x6x3m placed in a pond at size 5000m^2 with 3 m deep. Fresh water for the pond was obtained from Mekong River. Cages were placed in such way that provides sufficient water movement and exchange. Daily water quality measurement was performed and indicated that pH of water is stable at 8 and dissolved oxygen is 4, while daily temperature ranged from 28 to 32 °C.

Diets

Feeding trial used four dietary treatments comprise 1) Control diet without DDGS (DDGS 0 percent), 2) Test diet containing 50 g kg^{-1} DDGS (DDGS 5 percent), 3) Test diet containing 100 g kg^{-1} DDGS (DDGS 10 percent) and 4) Test diet containing 150 g kg^{-1} DDGS (DDGS 15 percent). Two types of diet were formulated for starter and grower which contain 28 percent and 26 percent protein respectively following common practice of Vietnam industries. The experimental diets were formulated to contain same nutrient content and presented in **Table 1**.

The size of pellet for starter feed would be 3-4 mm while for grower feed at 5-6 mm. Each dietary treatment was fed to *Pangasius* fish at size 40 g. The fish was grown in floating cage made of nylon net (mesh 1) at size 4x6x3 m (effective volume for water 72 m3) containing 300 fish per cage. Each treatment was replicated four times and the trial was performed for 118 days to reach marketable size which approximately 500 g. It was decided that after growth trial was completed, 50 fishes were kept in smaller cages and continued feeding the diets up to six months for fillet color measurement.

Table 1. Diet composition of Catfish feed containing different level of DDGS

	Starter Diet (280 g g/^{kg} protein)				Grower Diet (260 g g/^{kg} protein)			
Ingredients	**DDGS 0%**	**DDGS 5%**	**DDGS 10%**	**DDGS 15%**	**DDGS 0%**	**DDGS 5%**	**DDGS 10%**	**DDGS 15%**
Soybean meal, Arg.[1]	487.0	468.2	456.2	428.2	447.0	428.0	424.0	412.0
Rice bran, full fat	224.5	145.1	154.6	133.6	233.0	202.0	166.0	125.0
Wheat bran	0.0	0.0	0.0	0.0	50.0	50.0	50.0	15.0
Defatted rice bran	50.0	100.1	50.0	0.0	0.0	0.0	0.0	0.0
Cassava	120.0	120.1	120.1	165.1	120.0	120.0	120.0	120.0
Wheat	50.0	50.0	50.0	50.0	80.0	80.0	80.0	117.5
Fish meal, 62	40.0	40.0	40.0	47.5	30.0	30.0	30.0	30.0
Fish meal, 55	12.0	12.0	14.5	11.0	26.0	26.0	16.0	15.0
DDGS	0.0	50.0	100.0	150.0	0.0	50.0	100.0	150.0
Premix[2]	10.5	10.5	10.5	10.5	8.0	8.0	8.0	8.0
Salt	6.0	4.0	4.0	4.0	6.0	6.0	6.0	6.0
Mono Calcium Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
Total	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

1: Arg.= Argentina, 2: Premix contain Vitamin and Trace Element provided per kg of diet: iron, 50 mg; copper, 30 mg; manganese, 20 mg; zinc, 30 mg; cobalt, 0.1 mg; selenium, 0.1 mg. vitamin A (retinyl acetate), 7,000 IU; vitamin D3 (cholecalciferol), 1,000 IU; vitamin E (DL-α-tocopheryl acetate), 50 IU; vitamin K activity, 3 mg; thiamine, 6 mg; riboflavin, 7 mg; pantothenic acid, 15 mg; niacin, 40 mg; pyridoxine, 6 mg; folic acid, 2 mg; biotin, 0.1 mg

Feeding system

At least 6,000 fingerling of Catfish Basa at size 40 g (16 cages x 300 fish= 4800) was purchased from supplier and was adapted in the cages before the trial is started. Initially feed was offered at 5 percent biomass and fed four times per day at 7:30 am, 10:30 am, 13:30 pm and 15:00 pm. Amount of feed given was based on 95 percent satiation. Initial of feed was given at amount that can be consumed by fish within 10 minutes multiplied by 90 percent and was given in that amount for five days. The following five days was given at full amount therefore the average would be 95 percent satiation. This calculation was repeated again for every 10 day period.

Sampling and measurement of performance

Fish sampling was performed from every cage by collecting fish using a bucket after 42 and 78 days of feeding while total weighing was performed when they reached approximately 500 g at 118 days of feeding. The daily mortality and feed consumption was recorded. At end of feeding period (118 days), total fish were weighed from each cage and residual feed was measured. Feed conversion ratio was calculated and corrected for the mortality weight. DDGS samples were analyzed for proximate composition at Hung Vuong laboratory. Moisture, protein, crude fiber, ether extract and ash were analyzed according to Method EC 152/2009, TCVN 4328-1:2007, AOCS Ba-6a-05, ISO 6492:1999 and EC 152/2009, respectively.

Experimental grower diets were analyzed for AA contents at Evonik SEA Laboratory in Singapore. Samples (diets) for amino acid analyses were hydrolyzed in 6 *N* HCl for 24 h at 110 ℃ under nitrogen atmosphere. Performic acid oxidation was carried out before acid hydrolysis for methionine and cysteine analysis (AOAC International, 2000; 982.30 E [a, b, c]). The amino acid in the hydrolysate was subsequently determined by high performance liquid chromatography after postcolumn derivatization. Amino acid concentrations were not corrected for incomplete recovery resulting from hydrolysis.

Fillet color measurement

At end of feeding trial at 118 days, five fish samples were collected from each cage randomly, therefore total 20 fishes were collected from each treatment and the fillet was collected manually and weighed. Fillet yield was measured as percentage from total weight of fillet divided by weight of fish The fillet color measurement was performed using portable Nippon Denshoku NR-3000 color difference meter and expressed on L, a and b as Hunter Lab system. L value may indicate lightness and b indicates yellowness, while a value indicates redness. After growth trial was completed, it was decided to continue feeding DDGS to *Pangasius* until the size of fish reached around 0.9-1.0 kg and after 184 days, the fish sampling and color measurement of fillet was performed in similar method.

Statistical analyses

A randomized complete design with four treatments and four replicates containing 300 fishes per replicate cage was used in this trial for each species of fish. Data was analyzed using computer program (SAS ver. 6.12) and any significant different due to the treatment was further analyzed using Duncan.

RESULTS

DDGS and diet composition

Composition of corn DDGS used in this experiment is presented in **Table 2**. Protein content is 277.3 g g/kg while fat content is 98.8 g g/kg which indicate that this is a regular DDGS found in the U.S. with high oil content. Protein content estimated by near infrared spectroscopy is 276.5 g g/kg shows a similar result with protein content estimated by wet chemical method. Amino acids content in this DDGS is also a typical for U.S. corn DDGS with lysine level around 8 g g/kg and methionine 5 g g/kg.

Two types of feed were formulated to contain similar nutrient content when DDGS was included at 0, 50, 100 and 150 g g/kg. The composition of test diets for starter feed and grower feed is presented in **Table 3**. All starter or grower feed contains similar composition as expected. The starter feed contains 288-296 g g/kg protein and they are slightly higher than expected in formulation at 280 g g/kg. Similarly for grower feed, the analyzed protein content are 274-284 g g/kg, a slightly higher than expected in formulation at 260 g g/kg. Analyzed starch levels in all diets are around 300 g g/kg and this level is maintaining the same in all dietary treatments. High level of starch was formulated to produce floating feed.

The amino acids composition of grower feeds is presented in **Table 4**. There is a little variation in amino acids content among dietary treatments. Lysine content is maintained at around 16 g g/kg while methionine at 5.9 g g/kg. Those amino acids content is presented as total amino acids derived from feed ingredients and supplement. Analysis result indicated that all diet received only supplemental methionine at level 1.5-1.6 g g/kg feed. Total amino acids in all dietary treatments are 271-279 g g/kg and this figure would be similar to the result of protein content reported earlier.

Growth performance

Body weight of *Pangasius* fed different level of DDGS is presented in **Figure 1**. *Pangasius* grew well by feeding DDGS, body weight reached 150 g, 300 g and 470 g after feeding for 42, 78 and 118 days respectively. There is no statistical different in body weight among the dietary treatments at end of trial, however there is statistical difference due to treatment after feeding for 42 days. Feeding DDGS gave slightly higher body weight compare to control diet without DDGS. However the effect of DDGS disappeared after longer feeding at 78 and 118 days.

Performance of *Pangasius* after feeding different level of DDGS for 119 days is presented in **Table 5**. There is no statistical different on body weight of *Pangasius* after feeding different level of DDGS, although the highest body weight of *Pangasius* is found in fish fed highest level of DDGS (490 g) compare to control diet without DDGS at 471 g. There was no statistical different in feed consumption, which indicated that inclusion DDGS up to 15 percent did not affect palatability of *Pangasius* to consume feed. gain:feed ratio is also not affected by the dietary treatment but the lowest gain:feed ratio is found in fish fed 15 percent DDGS (1.53) compare the fish fed no DDGS or 50 g g/kg DDGS at 1.59 and 1.62 respectively. Mortality of fish was also not different among dietary treatment and the average mortality is between 3.7-4.9 percent.

Table 2. Composition of DDGS and essential amino acids level used in the trial

Analyzed Composition	Amount g g/^{kg}
Moisture	114.1
Crude protein	277.3
Crude fiber	76.9
Fat	98.8
Ash	45.0
Amino acids (Essential)	
Protein (NIRS)	276.5
Threonine %	10.02
Cystine %	5.02
Valine %	13.03
Methionine %	5.08
Isoleucine %	9.58
Leucine %	29.90
Phenylalanine %	12.74
Lysine %	7.91
Histidine %	7.28
Arginine %	11.79
Trytophan %	2.21

Table 3. Analyzed composition and starch level of diets containing different level DDGS (g g/^{kg})

Diet	Moisture	Protein	Fat	Fiber	Ash	Calcium	Phosphorus	Starch
Starter Feed, 280 g g/^{kg} Protein								
DDGS 0%	103.6	290.2	56.2	35.2	88.0	14.0	13.1	301.2
DDGS 5%	88.6	287.7	52.6	40.3	88.9	13.8	10.5	311.4
DDGS 10%	88.7	296.3	51.3	39.1	85.4	13.4	11.5	310.5
DDGS 15%	84.5	292.8	52.6	40.0	83.8	14.0	11.3	317.6
Grower Feed, 260 g g/^{kg} protein								
DDGS 0%	99.7	273.6	63.6	38.7	91.5	13.5	10.8	308.6
DDGS 5%	95.1	277.1	59.4	38.8	86.3	13.2	11.3	303.9
DDGS 10%	97.0	277.6	55.2	39.0	86.5	14.1	11.6	308.7
DDGS 15%	98.5	284.2	49.0	37.5	84.0	13.6	11.8	320.3

Table 4. Amino acids composition of grower diets containing different level of DDGS (g 100g^{-1})

Amino acids	**DDGS 0%**	**DDGS 5%**	**DDGS 10%**	**DDGS 15%**
Methionine	0.59	0.57	0.59	0.60
Cystine	0.42	0.42	0.44	0.43
Methionine + Cystine	1.01	0.99	1.03	1.03
Lysine	1.67	1.62	1.63	1.58
Threonine	1.13	1.11	1.14	1.13
Tryptophan	0.37	0.37	0.37	0.36
Arginine	2.07	2.03	2.05	2.00
Isoleucine	1.25	1.24	1.27	1.26
Leucine	2.12	2.15	2.29	2.32
Valine	1.39	1.38	1.42	1.41
Histidine	0.71	0.71	0.74	0.73
Phenylalanine	1.37	1.37	1.42	1.41
Glycine	1.43	1.43	1.46	1.46
Serine	1.41	1.40	1.45	1.43
Proline	1.54	1.60	1.70	1.72
Alanine	1.37	1.40	1.48	1.50
Aspartic acid	3.02	2.96	3.00	2.93
Glutamic acid	4.74	4.72	4.89	4.84
Total (without NH 3)	26.60	26.47	27.31	27.09
Ammonia	0.59	0.59	0.61	0.63
Total	**27.18**	**27.06**	**27.93**	**27.72**

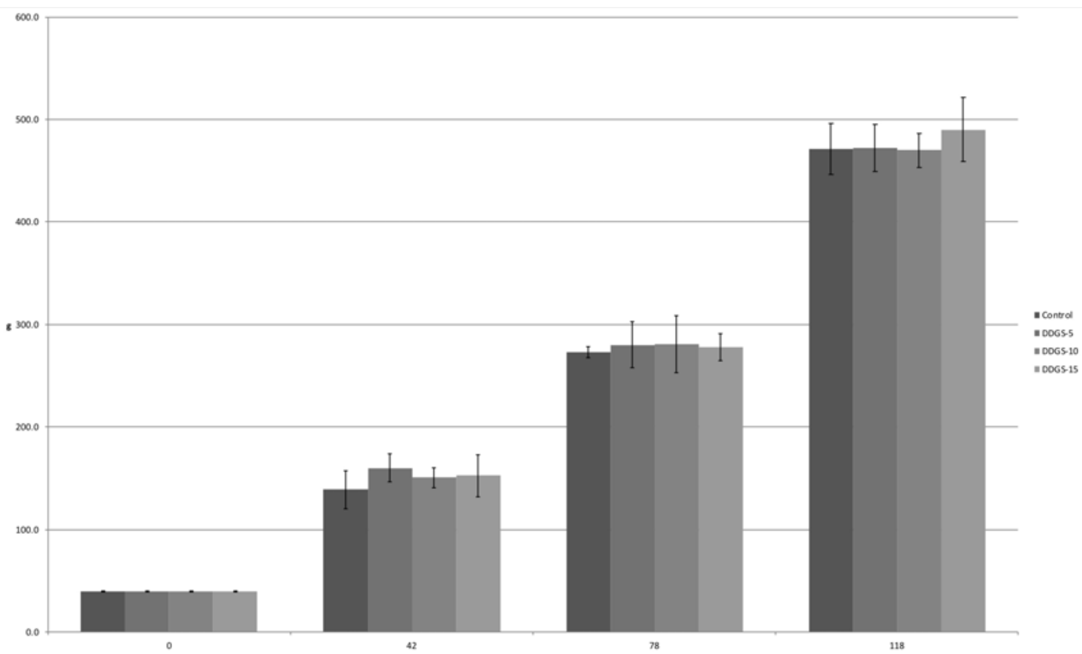

Figure 1. Body weight of *Pangasius* after feeding diet containing DDGS at different level

Table 5. Performance of *Pangasius* after feeding different levels of DDGS for 119 days					
Measurement	**DDGS 0%**	**DDGS 5%**	**DDGS 10%**	**DDGS 15%**	**SEM****
No of fish/cage	300	300	300	300	
Weight at start (g)	39.8	39.8	39.8	39.9	0.17
Weight at harvest (g)	471.3	472.0	470.0	490.2	24.6
Weight gain (g)	431.5	432.2	430.1	450.3	24.6
Feed consumption (g)	698.2	708.7	674.4	691.5	48.0
Mortality %	3.7	4.9	4.0	3.7	2.0
Gain:Feed	1.62	1.65	1.57	1.54	0.064
Gain:Feed corr*	1.59	1.62	1.56	1.53	0.055

*corr= corrected with mortality, ** SEM=Standard Error Means

Fillet color

Results on fillet color measurement of *Pangasius* after feeding different level of DDGS for 119 days and 184 days is presented in **Table 6 and 7** respectively while pictures of fillet is presented in **Figure 2**. Statistical analysis indicated that there was no significant different on color measurement of fillet after feeding 119 days. L, a and b value measured at anterior, middle and posterior position of fillet is not statistically different among dietary treatment. However there is difference in a value of fillet after feeding 184 days at anterior and posterior position but a value reflected redness in color while yellow color is reflected by b value and whiteness by L value. Yellow color of DDGS is originated from xanthophyll found in yellow corn and concentrated in DDGS during ethanol production. It seems that xanthophyll of DDGS is causing yellow color of fillet when DDGS is included up to 15 percent in the diet. Feeding DDGS for four months (119 days) did not affect fillet color and extended feeding up to six months also did not affect fillet color.

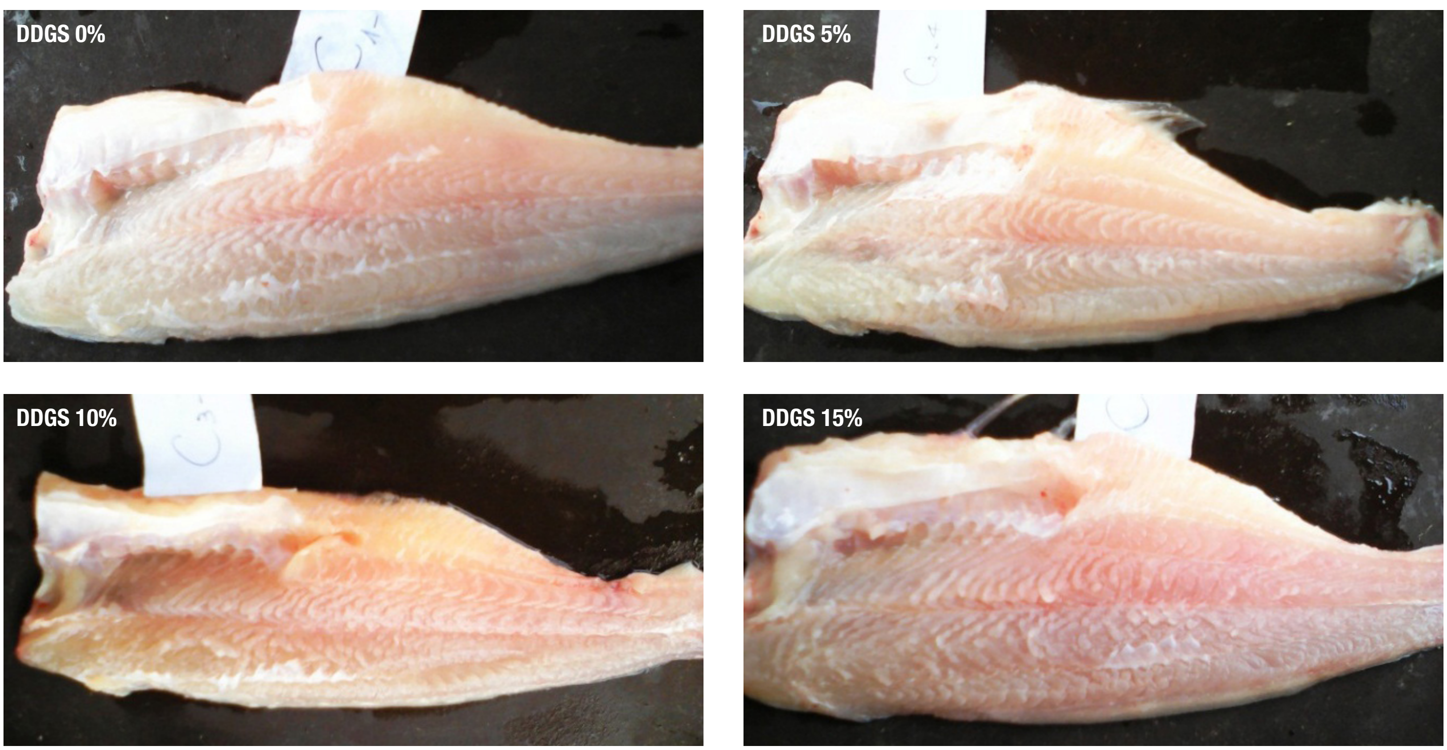

Figure 2. Fillet of *Pangasius* after feeding with different levels of DDGS for 118 days

Results on fillet yield measurement is presented in **Table 6** and fillet color measurements are shown in **Table 7**. Fillet yield was slightly improved by feeding the DDGS diets compared to the control diet, with no general effects on fillet color.

DISCUSSION

With increasing availability of DDGS due to ethanol production, DDGS can be potentially used for fish feeding. DDGS contains 277 g g/kg protein and fat 99 g g/kg can be used as source of a feed for fresh water fish. In this experiment, DDGS can be used to replace rice bran and partly soybean meal. In previous feeding trial to channel catfish, DDGS was used successfully to replace corn and soybean meal (Tidwell, et al., 1990, Zhou et al., 2010) and in combination with cottonseed meal, DDGS can replace soybean meal (Robinson and Li, 2008) as far as the diet was supplemented with lysine. In this experiment, when DDGS was used up to 150 g g/kg in *Pangasius* diet, the diet should be supplemented with DL methionine (1.4 g g/kg) but not lysine. It is possible that in the current experiment, the inclusion rate of soybean meal in the diets were very high (greater than 400 g g/kg) and soybean meal is well known to contain high amount of lysine (around 30.8 g g/kg) but soybean meal is deficient in methionine (6.8 g g/kg) (NRC, 1993).

Corn DDGS contains much lower lysine (7.9 g g/kg) compare to soybean meal and lysine in DDGS may be less digested for monogastric animals (Waldroup et al. 2007; Stein and Shurson, 2009). Therefore it is critical to formulate diet for fish carefully to consider amino acids composition and digestibility. Unfortunately digestible amino acids of DDGS for fish is not known, therefore digestibility coefficient of DDGS for poultry may be adopted. In the current experiment, the dietary treatments had been formulated to contain similar profile of amino acids as it is supported by the analysis result of amino acids content in the diets. DDGS however contains slightly higher crude fiber (76.9 g g/kg) compare to dehulled soybean meal (less than 35 g g/kg). High fiber may limit the utilization by fish but it depends upon inclusion rate and fish species. Recent report showed that DDGS inclusion rate should be limited to 100-200 g g/kg for rainbow trout (Welker et al., 2014) but can be tolerated up to 820 g g/kg in tilapia low protein diet if supplemented with synthetic lysine and tryptophan (USGC, 2012).

The diets containing DDGS up to 150 g g/kg in feed is readily consumed by *Pangasius* which may indicate that there is no palatability issue when DDGS is used in diets. The dietary treatments have been formulated to contain the same amount of starch (300 g g/kg) and all the feeds were able to float and there was no issue in manufacturing process. DDGS contain little starch as most of starch in corn

Table 6. Fillet yield and color of *Pangasius* fed different level of DDGS for 118 days

Treatment	Fillet (g g/kg)*	L anterior	a anterior	b anterior	L middle	a middle	b middle	L posterior	a posterior	b posterior
DDGS 0%	525.6[a]	46.48	-4.95	7.52	48.59	-5.52	6.04	47.97	-3.37	7.27
DDGS 5%	539.1[b]	47.23	-4.04	7.93	47.23	-5.14	7.74	48.58	-3.19	7.82
DDGS 10%	535.6[b]	46.81	-4.54	8.03	47.96	-3.50	7.53	47.83	-4.00	7.74
DDGS 15%	530.9[ab]	46.67	-4.76	7.83	48.59	-4.56	7.67	48.90	-3.93	8.56
P Value	0.030	0.595	0.755	0.851	0.463	0.332	0.268	0.449	0.685	0.268

*Different superscript in the same column indicate significant different (P less than 0.05)

Table 7. Fillet color of *Pangasius* fed different level of DDGS for 184 days

Treatment	L anterior	a anterior	b anterior	L middle	a middle	b middle	L posterior	a posterior	b posterior
DDGS 0%	46.50	-4.44b	-0.84	46.28	-2.23	-1.59	46.94	-1.24a	-1.21
DDGS 5%	46.61	-3.20ab	-0.45	45.73	-1.82	-0.27	47.08	-2.19ab	-0.30
DDGS 10%	46.61	-2.23a	-0.20	47.45	-3.10	-1.23	47.03	-3.53b	-0.21
DDGS 15%	47.52	-4.86b	-0.41	46.40	-2.74	-0.58	46.58	-1.18a	-0.08
P Value	0.288	0.040	0.804	0.089	0.439	0.145	0.950	0.024	0.392

*Different superscript in the same column indicate significant different (P less than 0.05) is converted to become ethanol and carbon dioxide during fermentation process. Therefore feed containing DDGS up to 150 g g/kg should be able to be manufactured for floating feed when starch level is considered.

Pangasius was able to grow well when DDGS was included up to 150 g g/kg in the diet. In the initial stage during growing (42 days), inclusion of DDGS in the diet was able to give better growth rate but the effect disappear on later stage of growing. Inclusion of DDGS may provide positive effect to tilapia, Wu et al. (1994) reported that diets containing either corn gluten meal (180 g g/kg) or DDGS (290 g g/kg) and 320 g g/kg or 360 g g/kg crude protein, resulted in higher weight gains for tilapia than fish fed a commercial fish feed containing 360 g g/kg crude protein and fish meal for tilapia with initial weight of 30 g. In a subsequent study, Wu et al., (1996) evaluated the growth responses over an eight week feeding period of smaller tilapia (0.4 g initial weight and concluded that feeding diets containing 320 g g/kg, 360 g g/kg and 400 g g/kg protein and 160- 490 g g/kg protein-rich ethanol co-products will result in good weight gain, feed conversion and protein efficiency ratio for tilapia fry. Previous study of feeding DDGS to tilapia in Vietnam indicated an improvement on survival rate when DDGS was included in the diet up to 150 g g/kg (Tangendjaja and Chien, 2007).

At the end of the feeding trial on DDGS, performance of *Pangasius* is not different among dietary treatments, inclusion of DDGS at 50, 100 and 150 g g/kg diet did not affect body weight gain, feed consumption and gain:feed ratio. Mortality was also not affected by feeding DDGS. The improvement on mortality found in tilapia trial was not noticed in this *Pangasius* trial. It is not known if there is species difference in mortality because of feeding DDGS. Lim et al., (2009) reported possible resistance of fish to Edwardsiella ictaluri challenge when the diets contain DDGS. However recent study by Overland et al., 2013 showed that feeding DDGS did not affect blood parameter of trout. DDGS contain residual yeast (*Sacharomyces cerevisiae*) from fermentation (Ingledew, 1999) and yeast cells especially cell wall has been reported by Li and Gatlin III, 2006 and Refstie et al., 2010 as sources of mannan oligosaccharides and β-glucans that can be used as immunostimulants in fish diets and finally influence fish health and reduce morality.

DDGS contains reasonable amount of xanthophyll if it is derived from yellow corn. The xanthophyll content may reach up to 59 mg g/kg and xanthophyll in DDGS has been shown that it can be transferred to yolk and improve the yolk color (Tangendjaja and Wina, 2011). Yellow color of yolk can be desirable for consumers, however yellow color may not be desirable for fish fillet consumers. Many *Pangasius* industries in Vietnam demanded that the fillet should have white in color and yellow color may not be desirable. In the present study, fillet color of *Pangasius* is not affected by feeding DDGS up to 150 g g/kg in the diet for 118 days and prolong feeding of DDGS until six months so the fish reached around 900 g size did not affect fillet color. It is important to note that Vietnam industries would normally harvest *Pangasius* to produce fillet for export when fish reach body weight around 1 kg. Previous study (Tangendjaja et al. 2012,unpublished) indicated that xanthophylls content of fillet of catfish fed 150 g g/kg DDGS is 1.1 ppm and no different in control diet without DDGS at 2.0 ppm, while xanthophylls content in DDGS is 30 ppm. This indicates that feeding DDGS 150 g g/kg did not increase xanthophylls content of the fillet of catfish and this result supports the result of color measurements of fillet in **Table 6 and 7**. The different results between coloring ability of DDGS for yolk and fillet may be associated with the different of tissue. Carotenoids including xanthophylls are compound that are soluble in fat and fat in egg is located in yolk rather than white albumen. In contrast to *Pangasius* fillet, that largely protein tissue, xanthophyll may not be deposited in the fillet and resulted that yellow color was not detected in *Pangasius* fillet after feeding DDGS up to 150 g g/kg in the diets.

CONCLUSIONS

Results from this study demonstrated that corn DDGS can be valuable for feeding *Pangasius* as source of protein and energy to replace rice bran and partly soybean meal. Feeding DDGS up to 150 g g/kg in the diet of *Pangasius* did not affect growth performance (body weight gain, feed consumption and gain:feed ratio) and mortality. Fillet color of *Pangasius* measured by color different meter was not affected by feeding DDGS for six months.

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REFERENCES

Association of Official Analytical Chemists (AOAC). 2000. Official methods of Analysis. 17th ed. AOAC, Arlington, VA.

Cheng, Z.J., Hardy, R.W., 2004. Nutritional value of diets containing distiller's dried grain with solubles for rainbow trout, Oncorhynchus mykiss. J. Appl. Aquac. 15 (3/4), 101–113.

Coyle, S.D., Mengel, G.J., Tidwell, J.H., Webster, C.D., 2004. Evaluation of growth, feed utilization, and economics of hybrid tilapia, Oreochromis niloticus × Oreochromis aureus, fed diets containing different protein sources in combination with distiller's dried grains with solubles. Aquac. Res. 35, 365–370.

Ingledew, W.M., 1999. Yeast — Could you base a business on this bug? In: Lyons, T.P., Jacques, K.A. (Eds.), Under the Microsope – Focal Points for the New Millennium – Biotechnology in the Feed Industry. Proceedings of Alltech's15th Annual Symposium, pp. 27–47.

Li, M.H., Oberle, D.F., Lucas, P.M., 2011. Evaluation of corn distiller's dried grains with solubles and brewer's yeast in diets for channel catfish Ictalurus punctatus (Rafinesque). Aquac. Res. 42 1424–1430.

Li, P., Gatlin III, D.M., 2006. Nucleotide nutrition in fish: current knowledge and future applications. Aquaculture 251, 141–152.

Li, M.H., Robinson, E.H., Oberle, D.F., Lucas, P.M., 2010. Effects of various corn distillers byproducts on growth, feed efficiency, and body composition of channel catfish, Ictalurus punctatus. Aquac. Nutr. 16, 188–193.

Lim, C., Yildirim-aksoy, M., Klesius, P.H., 2009. Growth response and resistance to edwardsiella ictaluri of channel catfish, ictalurus punctatus, fed diets containing distiller's dried grains with solubles. J. World Aquaculture Society. 40(2), 182-193

Øverland, M., Krogdahl,A., Shurson,G., Skrede,A., Denstadli,V., 2013. Evaluation of distiller's dried grains with solubles (DDGS) and high protein distiller's dried grains (HPDDG) in diets for rainbow trout (Oncorhynchus mykiss). Aquaculture 416–417, 201–208.

Refstie, S., Baeverfjord, G., Seim, R.R., Elvebø, O., 2010. Effects of dietary yeast cell wall β-glucans and MOS on performance, gut health, and salmon lice resistance in Atlantic salmon (Salmo salar) fed sunflower and soybean meal. Aquaculture 305, 109–116.

Robinson, E.H., Li, M.H., 2008. Replacement of soybean meal in channel catfish, ictalurus punctatus, diets with cottonseed meal and distiller's dried grains with solubles. J. World Aquaculture Society. 39(4), 521-527.

SAS Institute, 2002. SAS/Stats User's Guide. Version 9.1. SAS Inst. Inc., Cary, NC, USA.

Shelby, R.A., Lim, C., Yildrim-Aksoy, M., Klesius, P.H., 2008. Effects of distiller's grains with solubles-incorporated diets on growth, immune function and disease resistance in Nile tilapia (Oreochromis niloticus L.). Aquac. Res. 39, 1351–1353.

Stein, H., Shurson, G.C., 2009. The use and application of distiller's dried grains with solubles in swine diets. J. Anim. Sci. 87, 1292–1303

Tangendjaja, B., Chien, T.T., 2007. Use of dried distiller grain and solubles (DDGS) for feeding tilapia. Proc. IndoAqua Bali, July 30-August 1, 2007.

Tangendjaja, B., Wina, E., 2011. Feeding value of low and high protein dried distilled grains and soluble, and corn gluten meal for layer. Media Peternakan 34(1) 133-139

Tidwell, J.H., Webster, C.D., Yancey, D.H., 1990. Evaluation of distillers grains with solubles in prepared channel catfish diets. Transactions of the Kentucky Academy of Science 51:135-138.

USGC. 2012. A guide to Distiller's Dried Grains with Solubles. Third edition. Washington, D.C.

Waldroup, P.W., Wang, Z., Coto, C., Cerrate, S., Yan, F., 2007. Development of a standardized nutrient matrix for corn distiller's dried grainswith solubles. Int. J. Poult. Sci. 6, 478–483

Webster, C.D., Tidwell, J.H., Goodgame, L.S., Johnsen, P.B., 1993. Growth, body composition, and organoleptic evaluation of channel catfish fed diets containing different percentages of distiller's grains with solubles. The Progressive Fish-Culturist 55:95-100.

Webster, C.D., Tidwell, J.H.,Yancey, D.H., 1991. Evaluation of distillers grains with solubles as a protein source in diets for channel catfish. Aquaculture 96:179-190.

Wu, Y.V., Rosati, R.R., Brown, P.B., 1996. Effect of diets containing various levels of protein and ethanol co products from corn on growth of tilapia fry. Journal of Agricultural Food Chemistry 44:1491-1493.

Wu, Y.V., Rosati, R.R., Brown, P.B., 1997. Use of corn-derived ethanol co products and synthetic lysine and tryptophan for growth of tilapia (*Oreochromis niloticus*) fry. Journal of Agricultural Food Chemistry 45:2174-2177.

Wu, Y.V., Rosati, R.R., Sessa, D.J., Brown, P.B., 1994. Utilization of protein-rich ethanol co-products from corn in tilapia feed. Journal of American Oil Chemists Society 71:1041-1043.

Zhou, P., Zhang, W., Davis, D.A., Lim, C., 2010. Growth Response and Feed Utilization of Juvenile Hybrid Catfish Fed Diets Containing Distiller's Dried Grains with Solubles to Replace a Combination of Soybean Meal and Corn Meal. North American Journal of Aquaculture 72:298–303