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USE OF CORN DISTILLERS DRIED GRAINS WITH SOLUBLES (DDGS) AND FOOTS IN NILE TILAPIA FINGERLINGS DIETS

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ABSTRACT

The aim of this study was to investigate the use of corn distillers dried grains with solubles (DDGS) (27.11% CP) and Foots (20.84% CP) as corn processing by-products in monosex Nile tilapia, *Oreochromis niloticus* diets to replace yellow corn as an energy source and its effect on growth performance, nutrients utilization, whole body proximate composition, nutrients digestibility and economic efficiency. Three hundreds and seventy five fingerlings of Nile tilapia (10± 0.05 g) were randomly distributed into 15 circular plastic tanks (1000 L), representing 5 treatments. Isonitrogenous (25 to 25.84%) and isocaloric (4174.79 to 4364.65 Kcal GE/kg) experimental diets were prepared with substitution levels of DDGS 0% (T1), 20% (T2) and 40% (T3) and Foots 20% (T4) and 40% (T5). The experimental period lasted for 18 week. Results showed that both of DDGS and Foots have higher in all measured amino acids content than those in yellow corn except cysteine. Moreover, DDGS and Foots have higher content of linoleic, oleic, stearic and palmitic acids than those in yellow corn. Also DDGS and Foots covered the nutrient requirements of the essential fatty acid linoleic (18:2 ω 6) for Nile tilapia. Feed intake was significantly decreased as corn partially replaced by Foots more than the DDGS. Apparent digestibility coefficient of CP, EE, NFE and energy recorded the highest values for the T4 (75.76, 89.86%, 57.48 and 68.71%), respectively, followed by T3 with significant differences.

The increasing in substitution levels of yellow corn by DDGS did not significantly (P>0.05) had an effect on Nile tilapia performances. However weight gain and specific growth rate SGR were gradually decreased with increasing the substitution levels of Foots. The CP content of Nile tilapia carcass was significantly increased with increasing the substitution levels of DDGS (T3) and Foots (T5). Feed conversion ratio (FCR) of the fish fed diets T4 (20% Foots) was the best followed by T5 (40% Foots). The cheaper feed cost gain was obtained from T5 (40% Foots) followed by T4 (20% Foots).

INTRODUCTION

The rapid expansion of the aquaculture industry, along with the improvement and change in aquaculture techniques, have increased the demand for fish feeds. Feed is the primary expense for tilapia production and protein is the most expensive component. Yellow corn has traditionally been used in fish feed as major source of dietary energy. However, when the production of yellow corn is decline and prices increase, fish nutritionists are considering less expensive plant protein and energy sources. By products obtained from food manufactories such as starch processing from yellow corn may be considered alternative energy source that can be used in fish feeds.

Corn dried distiller's grains with solubles (DDGS) are the predominant corn co-product produced by dry-grind fuel ethanol plants consisting of distiller's grains combined with the condensed solubles obtained after yeast fermentation to produce ethanol **(Margareth et al 2013).** Yellow corn contains about two-thirds starch and most of starch is

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converted to ethanol during fermentation, the nutrients (protein, fat, fiber, ash and phosphorus) content of DDGS are 2 to 3 times more concentrated than in corn. Thus, the chemical composition of DDGS varies with the source and quality of grain used to produce ethanol **(Lim, and Yildirim-Aksoy, 2008). Patil et al (2015)** found that DM, CP, EE, CF, NFE, phosphorous and magnesium in corn DDGS were 89.7, 30.0, 9.8, 8.4, 47.2%, 0.83% and 0.28% respectively. **Schaeffer et al (2010)** demonstrated that DDGS does not contain anti-nutritional factors (e.g. trypsine inhibitors or gossybol) that present in soybean meal and cottonseed meal. Foots are corn co-products when using corn grains to produce starch by wet milling process. The grain must be separated into its components including starch, fiber, gluten and germ, (by soaking in water). The germ is removed from the kernel then, corn oil is extracted from the germ. Finally, Foots are generated via the filtration of the extracted oil. Nutrients in Foots are concentrated compared with yellow corn. So the present experiment was conducted to study the effect of replacing yellow corn by 0, 20, 40% DDGS and 0, 20, 40 % Foots in the diets of tilapia.

MATERIALS AND METHODS

This study was carried out at a commercial fish farm located in Kafr El-Shiekh Governorate, Egypt. Monosex Nile tilapia (*Oeochromis niloticus*) fingerlings of about 10 ± 0.05 g were obtained from private farm in Fayoum Governorate, Egypt. Fish were acclimated to the farm conditions for two weeks. During this period the fish were fed the control diets. After the accumulation period, about 50 fish were randomly selected and their body weight were recorded, then they were stored as a zero group at -40ºC for proximate analysis. The adapted fish were transferred to circular plastic tanks (1000 L), 375 fingerling were randomly divided into five experimental groups. The experimental diets were fed to fish in fifteen tanks (three replicates) so each tank contained 25 fingerlings. After the feeding experiments had finished, the same fish in each tank were fed 2% of the total biomass. The method used to collect feces from the bottom of the tanks was siphoning. Feces were collected for two weeks. The experimental period lasted for 18 week.

The five experimental diets were almost isonitrogenous (25 to 25.84% crude protein) and isoenergetic (4442.34 to 4748.65 Kcal GE/ kg). The percentage of yellow corn in the control diet was replaced by 0, 20 and 40% of DDGS T1, T2, T3 or 20 and 40% Foots (T4 and T5), respectively, as shown in **Table (1)**.

Growth performance

Growth performance parameters were calculated according to the following equations:

- Average weight gain (**Castell and Tiews 1980**).
  AWG (g/fish) = [Average final weight (g) – Average initial weight (g)]
- Specific growth rate (**Anderson et al 1984 and Tacon, 1987**).
  SGR = [Ln final weight (g) – Ln initial weight (g)] x 100 / experimental period (day).
- Feed conversion ratio (**Tacon, 1987**).
  FCR = [Feed intake, dry weight (g) / live weight gain (g).
- Protein efficiency ratio (**Hung *et al.* 1989**).
  PER = [Live weight gain (g) / protein intake (g)].
- Relative growth rate
  RGR (%) = [Average final weight (g) / initial weight (g)] x 100
- Protein productive value
  PPV (%) = [Final fish body protein (g) – initial' fish body protein (g) / crude protein intake (g)] x 100
- Energy utilization
  EU (%) = [Retained energy (kcal) /energy intake (kcal)] x 100
- Apparent digestibility coefficients (ADC %)
  = 100 - (100 [% Marker in feed / % Marker in feces] X [% Nutrient in feces /% Nutrient in feed])

The fish at the beginning of the experiments (zero time) and all samples of the fish from each tank at the end were separately punned in a mixer and dried at 65 ºC overnight and were applied to the chemical analysis. Feed ingredients, experimental diets, fish carcass and fecal materials were analyzed chemically to estimate moisture, crude protein (CP), ether extract (EE), crude fiber (CF) and ash content according to the methods of **A.O.A.C. (2012),** while nitrogen free extract (NFE) was calculated by differences. Analysis of amino acids for yellow corn and the tested materials were done according to the methods of **A.O.A.C. (2012).** Determination of total fatty acids in yellow corn and the tested materials was done by Chromatography Knauar HPLC pump 64 UV. Detector column: Ultracarb ODS (20) 250 x 4.6 mm.

Table 1. The experimental diets formulation (%) and chemical composition

Ingredients	T1	T2	T3	T4	T5
Yellow corn	42.00	33.60	25.20	33.60	25.20
DDGS	-	8.40	16.80	-	-
Foots	-	-	-	8.40	16.80
Soybean meal	22.00	22.00	21.00	22.00	21.00
Sunflower meal	7.00	7.50	8.00	7.00	6.50
Poultry by-products meal	11.50	9.00	7.50	8.00	6.00
Wheat bran	16.00	18.00	20.00	19.50	23.00
Vit. & min. mix*	0.50	0.50	0.50	0.50	0.50
Corn oil	1.00	1.00	1.00	1.00	1.00
Total	100	100	100	100	100
CP %	25.00	25.00	25.17	25.00	25.84
CF %	5.84	6.62	7.41	7.74	9.60
GE Kcal/kg	4442.34	4454.98	4471.19	4587.57	4748.65

*Each 1 kg contains: Vitamin A, 4.0 m.i.u; Vitamin D_3, 0.8 m.i.u; Vitamin E, 4.0g; vitamin K, 0.8 m.i.u; Vitamine K, 0.8g; Vitamine B_1,0.4g; Vitamine B_2, 1.6g; Vitamine B_6, 0.6g ; Vitamine B_{12}, 4.0g; Pantothenic acid, 4.0g; Nicotinic acid, 8.0g; Folic acid, 400.0mg; Biotine, 20.0g; Chlorine chloride, 200.0g; Copper, 4.0g; Iodine, 4.0g, Iron, 12.0g, Zink, 22.0g and Selenium, 0.04g.

**T1=control, T2=20% DDGS substituted by corn, T3=40% DDGS substituted by corn, T4=20% Foots substituted by corn and T5=40% Foots substituted by corn.

Statistical analysis of the obtained data were analyzed using the **SAS program (1999).** Differences were considered significant according to **Duncan (1955)**.

RESULTS AND DISCUSSIONS

Water quality

Results of water quality showed that dissolved oxygen ranged from 5.4 to 6.2 mg/l, water temperature from 26 to 30 ºC, pH from 7.0 to 7.5, ammonia from 0.08 to 0.10 mg/l, nitrite from 0.05 to 0.07 mg/l and nitrate from 4.0 to 5.0 mg/l. These values are laying with the normal values detected by **Masser (1997)**; **Redner and Stickney, (1979); Boyd (1990)**; **Ross (2000); El-Sherif and El-Feky (2008**) and **Froese and Pauly (2011).**

Chemical composition of the tested materials

Data of **Table (2)** clearly indicated that DDGS contain higher CP, NFE and ash than Foots. However, Foots contain higher EE, CF and GE than DDGS. Comparing the chemical composition of DDGS and Foots with yellow corn, crude protein, EE and GE contents in yellow corn represented 31%, 40% and 94% from those of DDGS content, respectively.

However, DDGS have higher contents of CP, EE, CF and GE than yellow corn. Also the same nutrients in yellow corn represented 40% (CP), 10% (EE) and 78% (GE) comparable to Foots. In this respect **Lim and Yildirim (2008**) reported that DDGS is a good source of energy and protein for various livestock animals.

Amino acids and fatty acids composition

The essential amino acids content (as percentage of DM) of DDGS and Foots compared to yellow corn are shown in **Table (3)**.

Table 2. Chemical composition (%) of yellow corn, DDGS and Foots

Ingredients	DM	CP	EE	CF	NFE*	Ash	GE (Kcal/kg)**
Yellow corn	89.00	8.51	3.78	2.61	83.81	1.29	4294.82
DDGS	86.78	27.11	9.39	9.11	50.00	4.39	4783.41
Foots	82.56	20.84	36.21	22.98	18.49	1.48	6258.10

* Calculated by differences.

** Calculated according to **Jobling, (1983).**

Table 3. Amino acids and fatty acids composition (% DM) of the distiller's dried grains with solubles (DDGS), Foots and yellow corn

Amino acids (%)	Yellow corn[1]	DDGS[2]	Foots[2]	Tilapia Requirements[3]
Iso leucine	0.28	1.06	0.77	0.87
Leucine	0.95	2.76	1.62	0.95
Lysine	0.24	0.84	0.91	1.43
Phenylalanine	0.38	1.26	1.00	1.05
Tyrosine	0.06	1.15	0.80	0.28
Threonine	0.26	0.96	0.79	1.05
Valine	0.38	1.30	1.23	0.78
Cysteine	0.89	0.48	0.33	0.15
Methionine	0.21	0.52	0.35	0.75
Arginine	0.39	1.16	1.27	1.18
Histidine	0.23	0.68	0.65	0.48
Fatty acids (%)				
Palmitic acid	0.62	1.23	1.32	
Stearic acid (18:0)	0.10	0.21	0.19	
Oleic (18:1)ω 9	1.17	3.51	2.69	
Linoleic (18:2)ω 6	1.82	4.85	5.51	
Linolenice (18:3)ω 3	0.09	0.07	0.06	

[1] Essential amino acid and fatty acids composition of yellow corn from Nutrient Requirements of Fish **(NRC, 1993).**

[2] EAA and F.A of DDGS and Foots were analyzed in the Center laboratory of Food and Feed, in ARC.

[3] Tilapia requirements according to **((NRC, 1993)**.

Tilapia require 10 essential amino acids in their diets for normal growth and metabolism. Specifically, fish have requirements for amino acids rather than crude protein (**NRC 1993**). Data of **Table (3)** showed that both of DDGS and Foots have higher in all measured amino acids content than those in yellow corn except cysteine. Lysine and methionine contents; are the most limiting amino acids required for fish and have highly figures compared to yellow corn (**NRC 1993**). However, the present results indicate that lysine and methionine contents of yellow corn represented 16% and 28% of tilapia requirements, respectively. Meanwhile, the essential amino acids, lysine and methionine represented (58 and 69%) and (63 and 46%) for DDGS and Foots of tilapia requirements, respectively. These results are in agreement with those obtained by **Gaylord and Barrows (2009); Shelby et al 2008) and Kiron (2012).**

Data of **Table (3)** showed that distillers dried grains with solubles (DDGS) and Foots have higher content of the all tested fatty acids than yellow corn specially the unsaturated fatty acids Linoleic acid and oleic acid. These results are in good agreement with those of **Lim et al (2011)** who showed that distillers dried grains with solubles (DDGS) owing to its high oil content, are rich in linoleic acid and are considered as an excellent source of energy and essential fatty acids for tilapia. The high ether extract content of Foots (36.21%) lead to high content of fatty acids. Therein Foots showed higher content of linoleic acid and palmitic acids comparable to DDGS as shown in Table (3). Both of DDGS and Foots covered the nutrient requirements of the essential fatty acid linoleic (18:2 ω 6) for Nile tilapia according to **NRC 1993**.

Digestibility

The apparent digestibility coefficients (ADC %) of CP, EE, NFE and energy of T4 recorded the significant (*P< 0.05*) of highest values (75.76, 89.86%, 57.48 and 68.71%), respectively, followed by T3 with significant differences **(Table 4)**. Whereas, the lowest digestibility coefficient values of CP, NFE and energy were obtained by T5 being 59.20, 36.43 and 52.60%, respectively, the control diet has the lowest (*P< 0.05*) digestibility coefficient value of EE (67.83%). The present results of the digestibility coefficient illustrate that increasing levels of DDGS instead of yellow corn owing to improve significantly (*P< 0.05*) the digestibility of all nutrients. Conversely, the increasing in substitution levels of Foots by yellow corn lead to significant (*P< 0.05*) decrease digestibility of CP, EE, NFE and energy comparing with the control diet. But the digestibility of EE was higher than the control. The decrease in CP digestibility of the diet T5 (40% Foots) may be reflects the high fiber content (Table 1) of this diet (**Sklan *et al.* 2004 and Anderson et al 1991)**.

Luiz, et al (2015) and Sklan et al (2004) recoded that apparent digestibility coefficient of energy was increased at high protein content of the diets and decreased with increasing crude fiber content. The crude fiber content showed a strong negative correlation with the ADCs of energy and nutrients in plant ingredients however, the ADC of energy and CP were significantly higher (*P*<0.05) in whole corn and corn gluten meal than in the other ingredients (corn germ meal and corn gluten feed).

Growth performance parameters

Growth performance parameters of Nile tilapia (*O. niloticus*) fed the experimental diets are presented in **Table (5).** Data showed non-significant decrease of feed intake, weight gain, FCR, PER, SGR and RGR as the level of DDGS was increased, while there were significant increase of PPV and EU. Also, non-significant decrease of feed intake and growth performance were observed as the level of Foots was increased, while FCR and PPV values were increased. The present results are in agreement with those obtained by **Lim et al (2007); Labib et al (2010) and Suprayudi et al (2015)** who reported that from the feed utilization results and economical point of view the diets contained 40% DDGS could be used in Nile tilapia diets.

Schaffer et al (2010) and **Schaffer et al (2009**) investigated the inclusion levels (17.5, 20, 22.5, 25 and 27.5%) of DDGS with 5% fish meal for juvenile tilapia (*Oreocromis niloticus*). They indicated that 20% DDGS achieved the highest apparent BWG among experimental diets, while 17.5% promoted the best feed conversion ratio (FCR) and PER. These results suggest that 20% DDGS can be included in tilapia diets containing 5% menhaden fish meal. The present results of the growth and feed efficiency parameters (FI, WG, FCR, SGR, RGR, PER, and EU %) for the fish fed diet T4 were the best values and these results reflect the high digestibility coefficient of EE, NFE and energy for the diet T4 which replaced yellow corn by 40% Foots (**Table 4)**.

Table 4. Apparent digestibility coefficients (ADC %) of nutrients

Treatments	CP	EE	NFE	Energy
T1	63.47 ± 0.16 D	67.83 ± 0.30 E	49.29 ± 0.28 D	52.63 ± 0.06 D
T2	68.02 ± 0.15 C	68.14 ± 0.14 D	48.05 ± 0.07 C	56.90 ± 0.18 C
T3	74.50 ± 0.24 B	88.98 ± 0.11 B	54.35 ± 0.16 B	65.16 ± 0.42 B
T4	75.76 ± 0.06 A	89.86 ± 0.06 A	57.84 ± 0.07 A	68.71 ± 0.13 A
T5	59.20 ± 0.39 E	78.58 ± 0.09 C	36.43 ± 0.09 E	52.60 ± 0.19 E

A, B, C..etc: Means in the same column with different superscripts are significantly different (P<0.05).

* T1=control, T2=20% DDGS substituted by corn, T3=40% DDGS substituted by corn, T4=20% Foots substituted by corn and T5=40% Foots substituted by corn.

Table 5. Feed intake, growth performance parameters, feed efficiency parameter and feed cost of Nile tilapia (*Oreochromis niloticus*) fingerling fed the experimental diets.

Treatments	T_1	T_2	T_3	T_4	T_5
FI g/fish	150.66 ± 2.29 A	146.26 ± 5.46 A	140.49 ± 2.76 A	123.76 ± 2.29 B	122.81 ± 0.20 B
WG g/fish	74.42 ±1.42 A	72.33 ± 2.77 AB	70.12 ±1.55 ABC	67.86 ± 0.82 BC	65.84 ± 0.54 C
FCR	2.02 ± 0.16 A	2.02 ± 0.00 A	2.00 ± 0.01 A	1.82 ± 0.01 B	1.86 ± 0.07 B
SGR %	1.53 ± 0.01 A	1.51 ± 0.01 AB	1.47 ± 2.76 ABC	1.48 ± 0.00 BC	1.46 ± 0.02 C
RGR %	698.41 ± 6.10 B	670.09 ± 8.93 B	633.17 ± 6.51 B	642.14 ± 4.31 A	612.52 ± 2.97 A
PER %	1.97 ± 0.47 B	1.97 ± 0.20 B	1.99 ± 0.15 A	2.19 ± 0.14 A	2.14 ± 0.19 A
PPV %	20.49 ± 0.50 B	20.66 ± 0.66 C	23.38 ± 0.18 B	22.66 ± 0.14 A	23.49 ± 0.21 A
EU %	12.58 ± 0.30	11.76 ±0.01	12.70 ± 0.10	13.34 ± 0.08	13.23 ± 0.11
Feed cost Kg gain	6.14	6.02	5.36	5.13	4.81

A, B, C..etc: Means in the same column with different superscripts are significantly different (P<0.05).

* T1=control, T2=20% DDGS substituted by corn, T3=40% DDGS substituted by corn, T4=20% Foots substituted by corn and T5=40% Foots substituted by corn.

Carcass composition of fish

The chemical composition of whole body parameters of Nile tilapia fingerlings fed diets contained 0, 20 and 40% DDGS or Foots as a partial replacement of yellow corn are summarized in **Table (6)**.

The highest CP content (55.73%) was detected in fish fed diet with 40% substitution of DDGS (T3) instead of yellow corn followed by T5 (54.93%) and T2 (53.45%), while, the lowest one was observed with fish feed the control diet (50.21%). Increase the replacement level of DDGS instead of yellow corn (20 – 40%) resulted significantly (*P< 0.05*) increase in fish body content of dry matter, crude protein, ether extract and energy content while, ash content was non-significant decreased. These results are in agreement with those obtained by **Labib et al (2010).** Also the increasing levels of Foots resulted significantly (*P< 0.05*) increase in CP and energy content, non-significant increase in DM and significant decrease in ash. **Robinson, et al (2001)** reported that the African catfish fed diet containing 50% corn gluten feed had a lower level of fillet fat than fish fed the control diet (0% corn gluten feed) however, reduction in body fat of fish fed diets containing corn gluten feed may be due to the lower digestible energy or digestible energy to crude protein ratio in the diet. These results are in agreement with the present study, that showed significant carcass fat decrease of fish fed diets contains Foots compared to the control.

Economic evaluation

The results of **Table (5)** clearly indicated that replacing 40% yellow corn by Foots recorded the lowest feed cost/kg gain (4.81 L.E) while control showed the highest cost (6.14 L.E). The present results of the cost of diets contained 40% DDGS as a partial replacement of corn are in agreement with those obtained by **Suprayudi et al (2015)** and **Labib et al (2010)** who demonstrated that cost of feed per unit of Nile tilapia gain fed diet contain 40% DDGS was the most effective and economical more the control.

Conclusion

The present data concluded that 40% DDGS can be included in Nile tilapia diets as a replacement of yellow corn without any negative effects on body composition. Also, the results detected that Foots level up to 40% efficiently support an optimal growth and was economically effective for Nile tilapia fingerlings.

Table 6. Carcass composition of monosex Nile tilapia (*Oreochromis niloticus*) fingerlings

Treatments*	DM %	CP %	EE %	Ash %	GE Kcal/kg
	A	F	A	D	B
T1	20.71 ± 0.04	50.21±0.10	16.90±0.04	18.11±0.16	5018.6±4.49
	B	D	E	B	D
T2	20.16±0.01	53.45±0.12	14.00±0.07	19.77±0.11	4856.12±0.11
	A	B	D	B	C
T3	20.66±0.11	55.73±0.08	15.70±0.07	19.39±0.16	4997.61±0.72
	C	E	B	C	B
T4	19.77±0.12	52.02±0.24	16.61±0.05	18.74±0.07	5015.73±2.30
	BC	C	C	D	A
T5	19.90±0.01	54.93±0.04	16.16±0.01	17.79±0.06	5066.82±7.05

A, B, C..etc: Means in the same column with different superscripts are significantly different (P<0.05).

* T1=control, T2=20% DDGS substituted by corn, T3=40% DDGS substituted by corn, T4=20% Foots substituted by corn and T5=40% Foots substituted by corn.

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