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Production and chemical composition of milk produced from dairy animals fed on the different types of corn milling co- products

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Abstract

Dairy animals' nutrition has an important role in influencing milk production and milk composition chemistry. But animal feeding is one of the high costs of production factors, so it is necessary to search for alternative sources, such as corn milling co- products. These products were studied and it was noted that they can affect the chemistry and quantity of milk positively or negatively. Most feed co-products of the corn had fast digestible cells and small, non-digestible residues, suggesting that they fit appropriately to feed lactating animals. The published net energy values of these corn co-products varied or were suspected from one study to another due to different factors such as interactions with different feed ingredients and level intake. Corn co-products are feed-rich products and can be used to support ruminant feed, but in specific proportions and depending on the type of production. Using corn co-products in dairy animal feeds should be carefully evaluated to avoid dietary imbalances and maintain protein quality. In this review, the most important results of some studies using different Corn co-products under various conditions were mentioned.
KeyWords: corn by-products, DDGS, corn bran, corn gluten feed, dairy animal nutrition.

1.Introduction

Corn is one of the most important grain crops in the world. About 52 % of the corn production is used for animal feed, while, 37 % is consumed in the production ethanol, and 11 % go to the food industries. Corn processing industries, such as the production of foods based on corn and the production of starch and ethanol result in some important by-products. Corn bran is an important type of these by-products. Theoretically, it is the coating of corn that is removed screened in the early stages of processing. However, the corn bran used for dairy animal feeding is mostly a mixture of the bran and other by-products. Based on the above, the product composition is highly variable. For example, in ethanol production, corn bran is a mixture of the bran fraction and corn syrup. In this case it is called corn gluten feed [1]. Therefore, there are more than one corn co-products that are considered corn bran depending on the processing method, for example, corn distillers' grains with soluble (DDGS) and corn gluten feed (CGF). It's known that in the management of dairy ruminants, the largest part of the production costs goes to feed costs. Therefore, the profitability can be increased by finding less expensive feed additives; those do not diversely affect animal performance and production. Special attention has been given to the corn ethanol industry as it produces a large number of co-products used as feeds for dairy animals. This industry produced 84,100 tons of dairy animal feeds [2]. Corn ethanol is produced by the fermentation of corn starch. Different ethanol production processes produce a variety of co-products. These co-products contain mostly protein, fiber, and fat. The fiber is derived from the corn pericarp or corn bran (CB), which is the outer layer (coating) of the corn seed [3]. However, compared with corn grain (CG), grain milling or fermentation co-products have a lower non-fibrous carbohydrate (NFC) and starch and higher neutral detergent fiber (NDF), crude protein (CP), and ether extract (EE) content. Corn bran as a ration additive has the advantage of being inexpensive; meanwhile, it has a very high energy value and an appropriate level of crude protein. So, it can be used for partial replacement of corn as a source of energy. Actually, the two main co-products are corn gluten feed (35.5 % NDF and 34.0 % NFC; [4] from wet milling, and distillers' grains with soluble (38.8 % NDF and 24.6 % NFC; [4]) from the conventional dry grind process. Corn gluten feed as well as distillers' grains with soluble have been shown

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to successfully substitute for a part of the forage mix or concentrate portion, or both, in dairy cow rations without detrimental effects on cow performance [5,6]. Also, Janicek et al., [7] did not observe any negative effect on lactating dairy cow performance when CB increased from 10 to 25 % dietary DM, replacing forage. This review focuses on the use of high fiber corn milling co-products containing the corn bran in the diets of dairy animals and their effect on the performance of productive dairy animals.

2.Processing Corn

Corn products have entered the field of the industry, since they have been introduced into dozens of industries that use starch, sugar products, dextrins, glues, and alcohol, medical and pharmaceutical materials. Therefore, these industries have left the remaining part after the manufacture of corn to become feed materials. These feeds are called Co-Products, and have not been named byproducts because of the importance of the foodstuffs contained in these materials. It is important to know how the corn is processed to know the properties of the feed material produced as a result of these processes. The methods of processing corn are divided into two categories: dry and wet. The dry treatment produces Distilled Dried Grains (DDG) and Distilled Dried Grains with Soluble (DDGS). The wet treatment produces Corn Gluten Meals (CGM), Corn Gluten Feed (CGF), Corn Germ Meal, and Corn Oil.

3. The Different Types of Corn Milling Co Products

Theoretically the corn bran is the outer layer that surrounds the corn grain. But practically the corn bran is the secondary products as a result of screening the corn grain during corn manufacturing. Therefore, there are more than one of corn milling co-products with a high content of fiber and are suitable for use in ruminant feeds. They are as follows:

1) Corn distillers' grains with soluble (DDGS).
2) Corn bran (CB).
3) Corn gluten feed (CGF).

4.Nutrient Composition of corn milling co-products:

The chemical composition of the corn milling co-products containing corn bran are different from the chemical structure of the corn grain **(Table 1)**. For example, an increase in the ratio of protein, fiber and mineral elements was observed in the corn milling co-products. However, the corn grain is superior to the high starch. It is also noted that DDGS has a higher fat content than the corn grain. The chemical structure tells us how to use these corn milling co-products in different proportions in dairy animal diets.

5. Advantages and disadvantages of corn milling co-products in animal feed:

5.1 Advantages

1) Cheap price compared to the corn grain or the grain meals.
2) They contain relatively high protein content.
3) They contain fiber ratios suitable for ruminants feed.
4) They contain high non-degradable protein.

5.2 Disadvantages

1) They contain a small percentage of starch so it is not suitable alone to cover the energy needs of animals.
2) Most corn products are poor in certain amino acids determined to produce milk such as lysine.
3) They need special storage conditions.
4) DDGS have a high percentage of fat and this can cause rumen acidity for animals.

Table 1: Chemical composition of corn and corn milling co products (dry matter basis)

Item %	Corn grain	Corn bran	CGF	DDGS
Dry matter	88	89	90	88.8
Crude protein	9.1	12-15	20-22	24-26
Crude fiber	2.2	6-9	6-8	5.4-8.5
Fat	4.2	1-1.5	2-3	11-12
Total starch	72	16-20	18-26	7-8
Ash	1.4	3.8	3-4	6-7

CGF = Corn gluten feed., DDGS = Corn distillers' grains with solubles.

6. The Effect of Using Corn Milling Co-Products as A Feed on Dairy Animal's Performance

Corn milling co-product feeds are mainly used as an energy source for ruminants. They are less expensive than corn grains, and depending on their chemical composition, their nutritional value may allow performing a little less, equal, or even better than whole grains.

6.1 Corn distillers' grains with soluble (DDGS):

Corn DDGS is a good source of protein for dairy cows. Protein content in DDGS is about more than 30 % based on dry matter (DM). DDGS is also a good source of ruminally undegradable protein (RUP), for ruminants [8]. DDGS has a higher level of rumen unprotected protein than found in corn, because the most of the degradable protein in corn is degraded during the fermentation process. Previous studies have shown that lysine amino acid is the first limiting amino acid for milk production [9,10]. So The quality of protein in corn DDGS is fairly good because, it poor in lysine as most corn co- products. In some studies, it has been proven that milk yield can be increased when dairy cows are fed rations containing supplemental ruminal protected lysine and methionine, or when DDGS is mixed with other high protein ingredients that contain more lysine. However, in most feeding diets containing soybean meal, results in milk production being as low, or lower, than when dairy cows are fed diets containing

DDGS as the protein source. It is also important to know that dark colored corn DDGS usually indicates heat damage of the protein, which may due to decreased milk yield. In a study by Powers et al., [11], dairy cows fed diets containing golden colored DDGS had higher milk production than cows fed diets containing dark colored DDGS. Therefore, it is important to use high quality sources of DDGS in dairy cow diets to maximize production of milk. Furthermore, Boucher et al., [12] concluded that when appropriate prediction equations are validated and identified, it can be possible to predict digestibility of RUP-amino acid from the amino acid digestibility in the intact feed because standardized amino acids digestibility and RUP-amino acids was highly correlated. Acid detergent insoluble crude protein (ADICP) concentration may be a good indicator of protein quality but, more of the variation in amino acid digestibility between DDGS samples is not explained by differences in ADICP concentrations. Also, Mjoun et al., [13] compared intestinal digestibility and ruminal degradability of protein and amino acids in soybean and (DDGS) products and noted that amino acid availability from (DDGS) products were identical to that of soybean mail. Corn DDGS is also a suitable energy source for dairy ruminants. Values of energy for high quality of DDGS are about 10 to 15% higher than the values you have accepted in NRC (2001). Corn DDGS contains a higher fat percent so, it has more energy than corn. Furthermore, because almost all of the starch in corn is turn into ethanol during the fermentation process, the fat and fiber concentrations in DDGS are increased three times compared to corn. Corn distillers' grains with soluble contain high levels of NDF but low levels of lignin. From the above we conclude that DDGS has a highly digestible fiber source for ruminants, and reduces digestive disorders compared to when corn is fed. High fiber digestion in corn DDGS also allows it to serve as an alternative to forages and concentrates in dairy rations. Nuez-Ortin and Yu [14] found that not different among the predicted energy values, but refinements of the NRC 2001 formula are needed for better prediction of crude protein and digestible NDF of these co-produces. When, compared the NRC 2001 chemical summary approach to an in situ assay approach for estimating energy content of wheat, corn and wheat-corn blends of DDGS.

6.2 Corn Bran (CB):

A few studies have examined the effect of corn bran on dairy animals' production because of the unavailability of this product and replacing it with corn gluten feed. Corn bran is a co-product of the wet corn process above, and is currently produced by adding corn condensed distillers soluble (CDS) to the bran part of the kernel. Most of the fat and protein fractions are contributed by CDS whereas most of the fiber comes from the corn grain pericarp. Its high content of fibrous carbohydrates and very little starch makes corn bran a good feed for ruminant diets. Corn bran contains a relatively low protein content varying between 9 and 15 % of DM, higher than corn grain but lower than corn distillers (DDGS) and corn gluten feed (CGF). Fiber content (crude fiber 5-20 % DM, NDF 20-60 % DM) tends to be higher than for other corn co-products, and much more variable. The advantages of high fiber supplements such as corn bran are that, although it is easy to digest, it does not increase the acidity of the rumen and increases the concentration of acetate, making it excellent for feeding dairy animals. Corn bran has a range of values from 1.60 to 3.66 % of Lignin on DM [15], which might suggest significant variation in this energy content. Furthermore, Tedeschi et al. [15] stated that it is variable factors that affect the degradation of neutral detergent fiber (NDF) also affect the predicted total digestible nutrients (TDN) values. The comparatively low protein concentration of corn bran has an advantage for nutrition scientists as the all amino acid protein balance can be improved through the inclusion of other feed with a higher lysine concentration. The cell wall content of corn bran varies widely, affecting digestion and thus on the energy level, despite the digestion rate is really good from the cell walls of the corn bran. The digestibility of corn bran approximately (70 % organic matter digestibility [16] and 76 % TDN in NRC, 2001) is generally considered to be 80 % that of corn grain. The ME content of corn ran is approximately 90 and 80 % of the corn gluten feed and grain, respectively. The net energy (NE) for gain of wet corn bran was estimated at 6.7 MJ/kg dry matter (DM) in case of fed at maintenance [17], a value consistent with the NE value for growth of 6.5 MJ/kg DM proposed [16]. In growing caw, fed on corn bran, it was in a positive effect on energy efficiency when it replaced 40 % of corn silage (DM basis), and it was concluded that it's in vivo OM digestibility was underrated [17]. When feeding steers, corn bran was found to have 100-108 % of the energy value of corn, which could be expounded by negative digestive interactions induced by dry-rolled corn in the control diet [18]. However, replacement dry-rolled corn and steam-flaked corn with corn bran decreased the gain: feed ratio by 5.2 and 13.8 %, respectively [19]. Corn bran, like many corn co-products, has high undegradable protein from 55 % to 60 % and it can be considered as the intermediate mediator of metabolizable protein 10.3 % DM [16]. Corn bran can be used to completely replace corn grain in the concentrate fed to production medium level of dairy cows without affecting milk quality [20]. Also, Tahir et al. [21] used, twelve Holstein Friesian cows of second and third lactation were randomly distributed into three equal groups. The animals of group A were fed on a concentrate mixture containing 30 % corn bran, group B animals on a concentrate mixture containing 30 % rice bran; whereas, the animals of group C on a concentrate mixture containing 30 % wheat bran. Corn fodder was given ad-lib to the cows of all groups. The experiment lasted for 60 days. They found that no significant differences between dry matter intake (DMI), crude protein and TDN in all groups. The milk fat and total solids were not affected by experimental rations. Significant variation was determined in solids-not-fat (SNF) of milk produced by animals fed on different experimental rations. The mains daily milk yields were 18.05, 12.87 and 14.65 L in groups A, B and C, respectively. The animals of group A showed significant better milk production which indicates the corn bran feed was nutritionally better and can be successfully utilized in the dairy ruminants ration to sustain production. In another trial by Mlay et al. [22], it was found that corn bran mixed with sunflower meal was significant increased milk yield. The advantage of corn bran is that it provides energy without causing negative digestive reactions with other ingredients. Also, supplementation of elephant grass (Pennisetum purpureum) with corn bran was increased the proportions of propionate, which may increase its metabolizable energy efficiency (ME), thereby increasing milk production [23]. A strategy in which corn bran only partially replaces corn grain and part of the forage may be preferable [24]. That is because when corn bran replaced dried corn grain in the concentrate portion of high-forage and low-forage diets, total replacement reduced organic matter (OM) intake, milk yield, milk energy, and milk protein.

6.3 Corn Gluten Feed (CGF):

Corn gluten feed (CGF) is a co-product of the wet-milling process, is a high fiber, low lignin feedstuff that has been frequently demonstrated to be a viable option for inclusion into lactating dairy ruminant rations [25.26]. Therefore, corn gluten feed generally is included in lactating dairy cow rations as a source of energy, protein and fiber. Its starch value is lower than corn grain, but, it contains three times as much crude protein. It is observed that when used corn gluten feed as an alternative to corn grains, it effectively reduces the level of non-structural carbohydrates of the diet with minimal effects on the energy ratio and this has a good effect. Many studies have evaluated the use of CGF in lactating dairy cow diets. Generally, it has been noticed to be an effective replacement for concentrate alone or forage and concentrate without significant impacts on DM intake or fat corrected milk production. Used, CGF as a supplement fed at 20 or 26 % of the diet DM increased milk production [27]. Van Baale et al., [28] showed increases in intake and milk yield for cows fed a diet supplemented with CGF compared to those fed a control diet containing both alfalfa hay and corn silage. Furthermore, López and Fernández [29 found that, milk production and DMI were similar for goats fed the diet based on corn than those for goats fed the diet based on fibrous by products (CGF). Moreover, milk fat and acetic acid were greater for goats fed soy hulls and corn gluten feed blend as a replacement for corn grain. This fibrous co-product was utilized by lactating goats without detrimental effect on energy metabolism and resulted in a similar performance to a traditional diet. The economic advantages and sustainability of this choice should be evaluated. Generally, either wet CGF or dry CGF can be an effective and efficient feedstuff for lactating dairy cows. It usually is priced lower than corn grain and reduces the amount of supplemental protein required. Thus, it generally will reduce the ration cost.

7. Effect of Increasing Amounts of Corn Milling Co-Products On Milk Yield and Composition

Increasing the production of biofuels from cereals such as corn leads to increased availability of corn milling co-products. Therefore, the levels of consumption of corn milling co-products should be increased in the feeding of ruminant animals, especially the dairy animals.

7.1 Increasing levels of corn distillers' grains with soluble (DDGS):

The inclusion of co-products such as corn distillers’ grains with soluble (DDGS) into dairy diets has been demonstrated to maintain milk production, but are usually fed in limited amounts because of the potential to negatively affect milk fat percentage [30]. Milk yield was not affected by the form of distiller’s grains fed, but there was a linear response to increasing distiller’s grains in lactating cow diets Table **(2)**. Dairy Cows fed diets containing from 4 to 30 % distiller’s grains produced the same amount of milk, approximately 0.4 kg/d more, than cows fed diets containing no distiller’s grains. Milk yield tended to decrease when dairy cows were fed the highest dietary inclusion rate more than 30% of DDGS. It was found that, these cows produced 0.8 kg/d less milk than cows fed no distiller’s grains. Cows fed more than 20% WDGS, it had decreased milk yield, which was related to decreased DMI. Some feeding studies evaluated reduced fat DDGS (RFDGS) in dairy cow diets. Mjoun et al. [31] concluded that RFDGS could successfully replace soymeal at inclusions of 10, 20 or 30 % of diet DM. Cows had no significant change in DMI and milk production between all levels. Milk had the highest fat percentages from cows fed 30% RFDGS, whereas milk from cows fed 10 and 20 % had a higher milk protein percentage. Also, in another trial by Mjoun et al. [32] they evaluated the inclusion of 20 % RFDGS and 22 % DDGS in early lactation diets. In this experiment, cows fed either DDGS diet had similar DMI and milk yield to cows fed soybean meal diets. Cows fed the DDGS diets produced milk higher in protein content and yield despite the relative lack of lysine. These studies concluded that RFDGS are a good source of metabolized amino acids and using 20 % of the RFDGS in dairy animal diets, did not reduce milk yield or milk protein production. In addition, Benchaar et al., [33] used twelve Holstein cows divided into four groups and fed a total mixed ration containing (dry matter basis) 0, 10, 20, or 30% DDGS. They found that, dry matter intake increased linearly, however digestibility of dry matter and energy decreased linearly as DDGS level in the diet increased. Increasing the ratio of DDGS in the diet decreased the acetate: propionate ratio, but this decrease was the result of reduced acetate concentration rather than increased propionate concentration. Milk yield increased linearly about 4 kg/day with increasing levels of DDGS in the ration and a tendency was observed for an increase in energy corrected milk as the ratio of DDGS in the diet increased. When increasing levels of DDGS in the diet (495, 490, 477, and 475 g/d for 0, 10, 20, and 30 % DDGS diets, respectively) methane production decreased

linearly. It was also found that the loss of CH4 decreased linearly with increasing the content of DDCS in the diets by 5, 8, and 14 % for 10, 20, and 30 % DDGS, respectively. Similarly, a decrease of CH4 production up to 12 % at DDGS ratio of 30 % when it was corrected for digestible energy intake. Methane production declined linearly as the amount of DDGS increased in the diet, when expressed relative to energy-corrected milk. Also, the amount of DDGS in the diet increased due to total nitrogen excretion increased. The increasing level of DDGS in the dairy animal diets cause declined linearly for efficiency of nitrogen utilization (milk nitrogen secretion as a proportion of nitrogen intake). But, when the levels of DDGS are increased in the diet, the nitrogen produced increases linearly, suggesting better efficiency of nitrogen use by the animal. Results from this study show that feeding DDGS to dairy cows can help to decreased CH4 emissions without negatively affecting intake and milk production. Inclusion of DDGS up to 20 % of the diet DM did not effect on dry matter intake, milk yield, or milk composition by the cows [34]. Also, Testroet et al., [35], reported that feeding 10 and 25 % DDGS (DM basis) in a TMR to lactating dairy cows resulted in significant milk fat depression and a concomitant increase of SNF and protein content of milk. However, the 25 % DDGS diet significantly increased ($P < 0.05$) stearic (C18:0), oleic (C18:1), and linoleic (C18:2) concentrations in milk. The reason that feeding DDGS increases unsaturated fatty acids content in milk fat may be, because corn oil contains greater than 60 % C18:2, some of which escapes the rumen without any biohydrogenation or with incomplete biohydrogenation, that way contributing to increases in the unsaturated FA found in the milk (particularly C18:1 and C18:2). Concentrations of no other FA in milk were affected by feeding DDGS. As the dietary concentrations of DDGS increased, rumen ammonia nitrogen linearly increased. Acetate proportion and acetate: propionate linearly decreased as DDGS increased, whereas propionate linearly increased. This causes a lack of fat in milk [36].

7.2 Increasing levels of Corn bran:

The combination between DDGS and corn bran when are included in the dairy animal diets, the probably should be not exceed 20 % of the diet DM to avoid milk fat depression. This results supported by Janicek et al., [7] where corn silage and alfalfa was replaced with corn bran at 10, 17.5 and 25 % of DM in lactating dairy cow diets. Milk yield also tended to increase, but no differences were noted on 3.5 % FCM. Also, milk fat percentage decreased by 0.26 %, but total fat yield was unaffected, when corn bran was increased from 10 to 25 % of the dairy animal diets. A common field concern related to feeding many corn milling co-products is the high fat content. It is now generally understood that a buildup of the unsaturated fatty acid, linoleic acid, in the rumen may due to events that can cause milk fat depression [37]. When corn bran levels were increased in the dairy animal diets from 10 to 25 %, the milk protein increased by 0.12 kg/day. Increased milk protein was due to greater milk energy status of cows consuming bran, as energy intake is positively correlated with milk protein synthesis [38]. Also, the diets containing bran may have provided more ruminal fermentable OM resulting in higher amounts of propionate for use in gluconeogenesis and amino acids being spared for protein synthesis [39]. One of their important findings was that feed conversion improved with the inclusion of corn bran in the diet reaching 1.55 kg of milk/ kg of DMI at 25 % inclusion rate. The use of corn bran in dairy ruminant feeds will be limited to the total fat in the diet. As with some high-fat feeds, it is possible that this product may happen to have fat oxidation after long periods of storage and may affect the susceptibility to palatability. Practically, health results of the previous studies suggest that the bran co-product is a feedstuff with high nutrient quality but should be included into dairy diets balanced to contain adequate levels of effective fiber [7] .

7.3 Increasing levels of Corn gluten feed:

Bernard et.al. [40] reported significant variation in nutrient composition of CGF. Therefore, limiting the amount of CGF to 10-20 % of the dairy animal diets will minimize the impact of these variations upon the total diet. In addition, changes in DM content and spoilage should be considered when wet CGF is fed. In a study managed by Mullins et al. [41] to study the effects of increasing dietary rates of wet corn gluten feed (WCGF) on milk production and rumen parameters of dairy cow. They were used diets containing 0, 11, 23, and 34 % WCGF on a DM basis. Increasing dietary WCGF linearly increased dry matter intake (26.7, 25.9, 29.3, and 29.7 kg/d) and milk yield (36.8, 37.0, 40.1, and 38.9 kg/d) with (0, 11, 23, and 34 % WCGF, respectively). Milk components concentrations did not affect with different treatments; but, lactose and protein yields increased linearly and fat yield tended to increase linearly when increasing levels of WCGF in dairy animal feds. This leads to increased production of solids corrected milk (35.2, 35.7, 38.5, and 37.2 kg/d) and energy corrected milk (38.2, 38.8, 41.7, and 40.4 kg/d), but efficiency of production linearly decreased. The increasing level of WCGF in the animal diet tended to linearly decrease ruminal pH (6.18, 6.12, 6.14, and 5.91), possibly because the average particle size was less than the typical recommendations for all diets, the diets had larger proportions of small particle size of WCGF. Moreover, ruminal propionate increased linearly and acetate concentration decreased linearly as WCGF inclusion rate increased. Treatments had an effect on ammonia concentration, with increasing concentrations for the 0 and 34 % WCGF diets. In another study by Rezac et al. [42] used lactating dairy cows were fed diets with different levels of wet corn gluten feed (WCGF) 33 % low (LG), 46 % medium (MG) and 56 % high (HG). They found that milk yields were 36.2, 34.6, and 35.2 kg/d for LG, HG, and MG, respectively, and were not significantly different. Regarding, milk fat concentration was higher for LG and HG than for MG, (3.48, 3.41, and 2.82 %, respectively). Fat yield was significantly increased for LG compared with HG and MG. Milk urea nitrogen was highest for HG and MG and least for LG, consistent with differences in dietary protein content. As for its productive efficiency, it was expressed by energy-corrected milk divided by the amount of dry matter intake, was 1.47, 1.42, and 1.24 for LG, HG, and MG, respectively, and was not significantly different. These data indicate that NG group did not adequate NDF to uphold normal rumen function in mid lactation dairy cows; instead, HG may be a feasible diet for use on dairies where high-NDF grass hay and WCGF are available. Also, Sullivan et al. [43] reported that, ruminal pH was not affected, but DMI and milk yield increased with increasing WCGF in the animal diet. Milk fat, lactose, and protein contents were not affected by all treatment; but, milk lactose and protein yields increased with the inclusion of WCGF because of the increased milk yield. Also, production efficiency was not affected by treatments. Therefore, it is possible to provide the ratio of the use of the CGF, provided that the size of the optimal particles, which leads to increased milk production and production efficiency without increasing the pH in the animal rumen. In brief, **Fig 1** shows the effect of increasing corn milling co-product levels on milk production and its components.

Table 2: Dry matter intake and milk yield of dairy cows fed increasing levels of distiller's grains as either dried or wet

Inclusion level	DMI, kg/d Dried	DMI, kg/d Wet	DMI, kg/d All	Milk, kg/d Dried	Milk, kg/d Wet	Milk, kg/d All
0%	23.5^{c}	20.9^{b}	22.2^{b}	33.2	31.4	33.0
4 – 10%	23.6b^{c}	23.7^{a}	23.7^{a}	33.5	34.0	33.4
10 – 20%	23.9^{ab}	22.9^{ab}	23.4^{ab}	33.3	34.1	33.2
20 – 30%	24.2^{a}	21.3^{ab}	22.8^{ab}	33.6	31.6	33.5
> 30%	23.3^{bc}	18.6^{c}	20.9^{c}	32.2	31.6	32.2
0%	23.5^{c}	20.9^{b}	22.2^{b}	33.2	31.4	33.0

a,b,c Values within a column followed by a different superscript letter differ (P < 0.05).

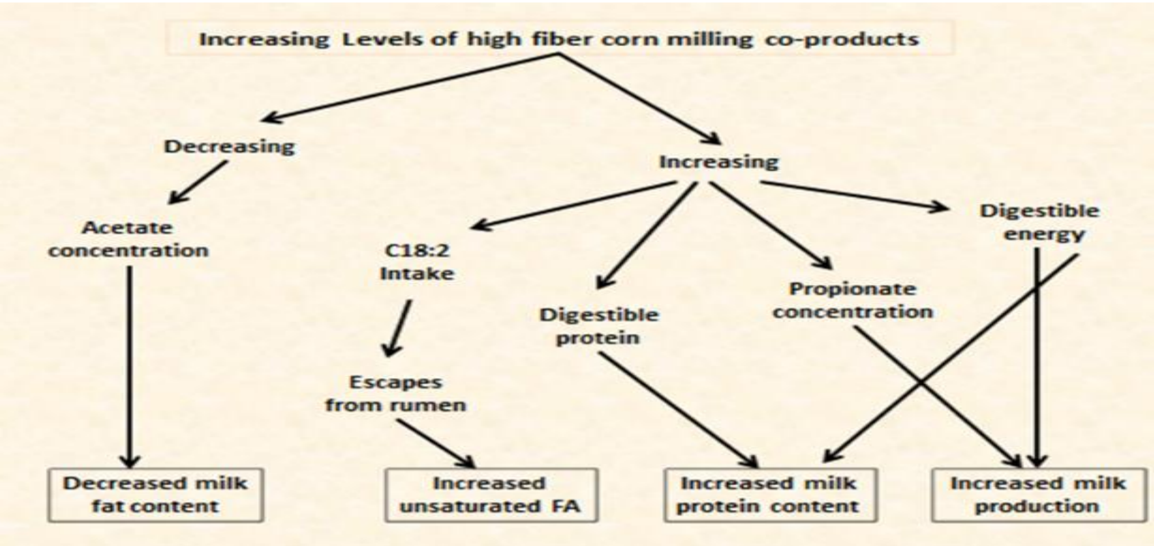

Figure 1: The effect of using high percentages of corn milling co-products on lactating animals' performance

8. Factors Determining the Level of Corn Milling Co-Products in Dairy Animal Diets

After reviewing some of the previous studies, it was observed that the corn milling co-products can be increased in dairy animal diets at specific rates depending on:

1) Type of the corn milling co-products
2) The formula of the animal diets and its type
3) The size of the corn milling co-products particles

9.Conclusion

Corn milling co-product feeds, mainly the corn bran, corn gluten feed and distillers' grain with soluble are materials rich in proteins and energy for dairy animals. Therefore, research recommends their use as alternatives for expensive sources of protein, energy and minerals. Corn milling co-product feeds are variable. So that, it is recommended to precisely determine the compositions of nutrients in order to properly and efficiently formulate the diets. It is critically important to provide sufficient amount of fiber to the diet in order to keep normal rumen function and consequently prevent the depression in milk fat. Special concern should be given to concentrations of nitrogen and phosphorus in corn milling co-product feeds in order to prevent their excessive losses to the environment. More work is needed to determine the types of feeds which may be replaced by corn milling co-products. This will result in enhancing animal productivity, decreasing the negative impact on environmental and finally reducing the cost of milk production.

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