Role of Dairy Cattle in Converting Feed to Food

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Abstract

The net contributions dairy cows make to the food system in the United States are not necessarily well understood by consumers. Estimates of nutrient conversion efficiency are sometimes used to describe these contributions but are often poorly documented or based on dubious assumptions. The main objectives of the first study were to: 1) define coefficients to calculate human-edible fractions of major dairy feed ingredients used in the United States, and 2) estimate the share of the dairy ration that is human-edible on a national level using these coefficients. The analysis was performed on a national average dairy ration computed from 350 farm surveys used in the carbon footprint life cycle assessment for fluid milk. The national average ration includes weighed rations for calves, open heifers, bred heifers, first-calf heifers, springers, lactating cows, and dry cows, and accounts for forage grazed during the year. The national average ration includes 33 ingredients and contains 53% forage and 47% concentrate (DM basis). Food, fuel, and fiber industry by-products (14 ingredients) account for 19% of dairy feed DM. Eight major crops account for 80% of dairy feed DM (corn 42%, alfalfa 22%, wheat 3.1%, soybean 3.0%, canola 1.8%, sorghum 1.7%, barley 1.4%, and cottonseed 1.4%). Two coefficients were calculated to estimate human-edible fractions of each ingredient. The composition coefficient was calculated as 1 minus NDF content (except for cottonseed where oil content was used). The non-NDF fraction was considered human-edible if it does not contain toxic compounds, and ingredients containing more than 30% NDF were excluded. The demand coefficient was calculated by multiplying the first coefficient by the proportion of total ingredient production currently demanded by the U.S. food industry. This coefficient incorporates current consumer demand, preferences, and eating habits.The amount of human-edible dairy feed is either 20 or 2.2% of ration DM when using composition and demand coefficients, respectively. Dairy cows make a net positive contribution to food supply in the United States by converting significant amounts of otherwise unusable plant matter in feed into food.

Introduction

The net contributions dairy cows make to the food system in the United States are not necessarily well understood by consumers. The belief that dairy cattle compete directly with humans for food is based on the misperception that dairy feed and human food are interchangeable. In addition, estimates of nutrient conversion efficiency are sometimes used to describe dairy cattle as inefficient. However, these estimates often rely on dubious assumptions, poorly documented coefficients, and ignore the ability of dairy cattle to convert human-inedible plant matter into nutritious dairy products.

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Descriptive Analysis of How Dairy Cows Convert Feed into Food in the United States

This study evaluated the feed ingredients consumed by dairy cattle in the United States with the goal of determining the portion of dairy feed that could be potentially consumed directly by humans. To provide a better understanding of the extent dairy contributes to or detracts from the current food supply in the United States, this study focused on the following objectives:

1. Define composition and demand coefficients to calculate human-edible fractions of major dairy feed ingredients used in the United States, and
2. Estimate the share of the dairy ration that is human-edible on a national level using these coefficients and supply and demand analysis of the crops from which these ingredients originate.

Definition of composition and demand coefficients

The descriptive analysis was performed on a national average dairy ration computed from 350 farm surveys conducted for the life cycle assessment study on greenhouse gas emissions from production of fluid milk in the U.S. (Thoma et al., 2013). The national average ration includes weighed rations for calves, open heifers, bred heifers, first-calf heifers, springers, lactating cows, and dry cows, and accounts for forage grazed during the year.

It became clear early in the analysis that although some dairy feed ingredients can be used directly in human food products, their current demand by U.S. consumers can be very small or they are not economically viable substitutes for current foodstuffs. Therefore, 2 distinct coefficients were developed to describe the human-edible fractions of dairy feed ingredients based either on their chemical composition or U.S. food industry demand.

The *Composition Coefficient* was calculated to define human-edible fractions based on chemical composition as: ***1-NDF content*** (with one exception; see cottonseed below). The composition coefficient excludes NDF because humans cannot digest and extract nutrients from fiber – the non-NDF fraction was considered human-edible if it does not contain toxic compounds. The oil content was used to calculate the composition coefficient for cottonseed instead of 1-NDF content because cottonseed contains the toxic compound gossypol but its oil is human-edible. The composition coefficients for ingredients containing more than 30% NDF which were set to zero because they were considered unsuitable for human consumption.

The *Demand Coefficient* was calculated to define human-edible fractions based on the United States food industry demand for that ingredient as: ***composition coefficient x percent food use of total domestic use***. Percent food use of total domestic use for corn grain and barley were calculated by dividing the food use by the total domestic use from USDA supply and disappearance balance sheets averaged over the 5-year period from 2009 to 2014. Percent food use of total domestic use for cottonseed was obtained from the National Cottonseed Products Association. The demand coefficient adjusts the composition coefficient by current demand for that ingredient by the United States food industry and reflects the food industry's response to current consumer preferences and eating habits.

Composition and demand coefficients were not calculated for protein mix, supplement, grain mix, partial mix ration, and miscellaneous because they represent mixes with variable

and uncertain composition (these 5 ingredients account for 14% of diet DM). Composition and demand coefficients were not calculated for soy hulls, molasses, whole roasted soybeans, hominy, beet pulp, sorghum grain, and whey because their inclusion rates are less than 1% and would have only a negligible impact on the human-edible portion of the national average dairy ration (these 7 ingredients account for 3% of diet DM).

Composition of the national average dairy diet

The national average dairy diet includes 33 ingredients. Ten ingredients are forages that account for 53% of diet DM, and 23 ingredients are concentrates that account for 47% of diet DM (Figure 1). The national average dairy diet also includes 14 by-products from the food, fuel, and fiber industries that account for 19% of diet DM (Figure 1). Only 1 by-product (wheat straw) is considered a forage while the other 13 by-products are considered concentrates, even though they may contain considerable amounts of NDF (Figure 1).

Eight major crops account for the 80% of the national average dairy diet DM (Figure 2). Supply and demand analysis indicates that dairy feed primarily demands corn and alfalfa (Figure 2), while the human food industry primarily demands wheat, oilseeds, and barley (Figure 3).

Human-edible fraction of the national average dairy diet by composition

Composition coefficients were defined as zero for 13 ingredients representing 56% of diet DM because they contain more than 30% NDF and are unsuitable for consumption as food by humans (corn silage, alfalfa silage, wheat silage, sorghum silage, oat silage, alfalfa hay, oat hay, grass hay, wheat straw, pasture, citrus pulp, almond hulls, and cotton gin trash).

No forage crops (i.e., silage, hay, straw, and pasture) were considered suitable for human consumption. This is due to the difference between the human digestive system and the ruminant digestive systems of cattle, sheep, and goats. A large portion of the energy in forage crops is in the forms of cellulose or hemicellulose, which "are inefficiently digested by monogastrics and are not digestible by man" (CAST, 2013). Silage crops include corn silage, alfalfa silage, wheat silage, sorghum silage, and oat silage. Altogether, these feed ingredients account for 36.8% of the DM in the national average dairy diet. Corn silage represents 22.4% of dietary DM and is by far the largest single contributor to the national average dairy diet. Wilkinson (2011) specifically addressed the use of corn silage for human consumption, stating "the maize hybrids grown for silage are different to those grown for sweet corn [hybrids demanded by the food industry] and no part of the plant is considered suitable for human consumption." Citrus pulp, almond hulls, and cotton gin trash are by-products of the citrus, almond, and cotton processing industries, respectively. None of these ingredients are fit for human consumption, but ruminants are able to eat, digest, and turn them into animal-derived food products suitable for human consumption. Dairy cattle therefore offer a way to turn plants and plant by-products unsuitable for human direct consumption into nutritious dairy and meat products.

Composition coefficients were calculated for 8 dairy feed ingredients that originate from 5 crops and represent 26.3% of the national average dairy diet DM (Table 1). These ingredients include grain corn, high moisture corn grain, distiller's grains, corn gluten feed, cottonseed, soybean meal, canola meal, and barley. *Twenty percent of dairy feed is human-edible by composition* according to this analysis (Table 1).

Human-edible fraction of the national average dairy diet by U.S. food industry demand

Demand coefficients were defined as zero for distiller's grains, high moisture corn grain, corn gluten free, soybean meal, and canola meal (Table 1). Distiller's grains are primarily produced from corn in the U.S. and is a by-product of the ethanol industry. Distiller's grains contain fiber and protein that remains after the starch has been converted to ethanol. Although distiller's grains can be blended with wheat flour and used in baked goods, the U.S. food industry does not demand any distiller's grains, except for minute quantities used in novelty and research baked goods to show proof of concept. High moisture corn kernels are harvested at 24% or greater moisture before fermenting and storing in a silo to use as livestock feed. The high moisture content makes transporting, keeping it insect and mold free, and ultimately drying high moisture corn prohibitively expensive. Therefore, it is unlikely that the U.S. food industry would ever demand high moisture corn grain for processing into food products fit for human consumption. Corn gluten feed is a by-product of industrial corn milling operations and contains protein and fiber. Corn gluten feed is not demanded by the U.S. food industry due to its fiber content and strong fermented taste. In addition to animal feed, corn gluten meal is used as a soil amendment and pesticide. Soybean and canola meals are co-products of the oilseed crushing industry. After crushing, the oil is primarily used in the food sector as a component of vegetable oil and the meal is used as a source of protein in livestock feed. Soybean and canola meals are not included in human food products and therefore are not demanded by the U.S. food industry.

Demand coefficients were calculated for corn grain, cottonseed, and barley (Table 1) by multiplying percent food use of total domestic use by the corresponding composition coefficient. Corn grain can be used in human food products after milling and conversion to high-fructose corn syrup, glucose and dextrose (sweeteners), starch, beverage alcohol, and cereals. Food use for corn grain was calculated by summing domestic use values for those food products (Table 2). Starch and alcohol for beverages and manufacturing were included in the sum although both have non-food uses (e.g. drywall for building construction for starch) because non-food use data were not available and the amounts are likely negligible for the purposes of our calculations given the large value for total domestic use (demand coefficient for corn grain: 0.91 x 0.12 = 10.9%).

Barley is commonly used in both human food and animal feed. Food for barley use was calculated by dividing food, alcohol, and industrial use by total domestic use (Table 3). Although food, alcohol, and industrial use of barley includes non-food uses, their amounts are likely negligible for the purposes of our calculations given the relatively large value for total domestic use (79 x 0.72 = 57%).

Cottonseeds contain gossypol, a compound that is toxic to humans. Cottonseed is used by the oilseed crushing industry to extract oil that can be included in vegetable oil products for human consumption. The oil content of cottonseed is 16% of DM according to the National Cottonseed Products Association (NCPA, 2016), and 90% of cottonseed oil produced is used for human consumption, predominantly in salad or cooking oil and to a lesser extent in the production of baking and frying fats (demand coefficient for cottonseed: 16 x 0.90 = 14%).

Using the demand coefficients described above suggests that *2.2% of dairy feed is in demand by the food industry in the United States,* primarily in the form of corn grain and barley (Table 1).

Conclusion

Dairy feed is not primarily composed of human-edible cereal grains and oilseeds. Dairy cows convert feed into food by recycling nutrients in human-inedible agricultural and industrial by-products into nutritious milk and dairy products. The competition between dairy feed and human food is negligible and dairy cows make a net positive contribution to the food supply in the United States.

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Table 1. Composition and demand coefficients for human-edible dairy feed ingredients.

Ingredient[1]	Composition coefficent[2]	Demand coefficient[3]	Edible by composition[4]	Edible by demand[5]
Corn grain	0.91	0.109	8.8%	1.05%
Distiller's grains	0.61		2.5%	
High moisture corn grain	0.90		2.5%	
Corn gluten feed	0.65		1.7%	
Cottonseed	0.16	0.144	0.4%	0.32%
Soybean meal	0.88		1.7%	
Canola meal	0.70		1.3%	
Barley	0.79	0.570	1.1%	0.80%

[1]Percent DM in the national average dairy diet: corn grain (9.7%), distiller's grains (4.1%), high moisture corn grain (2.8%), corn gluten feed (2.6%), cottonseed (2.0%), soybean meal (1.9%), canola meal (1.8%), and barley (1.4%). These 8 ingredients represent 26.3% of the total national average dairy diet DM.

[2]Composition coefficients were calculated as 1-NDF using NDF values (on DM basis) from Dairy NRC (2001) (corn grain = 9.5%, distiller's grains = 38.8%, high moisture corn = 10.3%, corn gluten feed = 5.5%, soybean meal = 12.3%, canola meal = 29.8%, and barley = 20.8%), except for cottonseed were oil content was used (16% on DM basis).

[3]Demand coefficient was calculated by multiplying the composition coefficient by the percent food use of total domestic use (corn grain = 12%, cottonseed = 90%, and barley =72%).

[4]Edible by composition was calculated by multiplying each ingredient's composition coefficient by its corresponding amount in the national average dairy diet on a DM basis.

[5]Edible by demand was calculated by multiplying each ingredient's demand coefficient by its corresponding amount in the national average dairy diet on a DM basis.

Table 2. U.S. corn domestic and food use for marketing years (Sep-Aug) 2009 to 2014.

	09/10	10/11	11/12	12/13	13/14
High-fructose corn syrup (HFCS)	512	521	512	491	478
Glucose and dextrose	257	272	294	292	308
Starch	250	258	254	249	219
Alcohol for fuel	4,591	5,019	5,000	4,641	5,124
Alcohol for beverages and manufacturing	134	135	137	140	142
Cereals and other products	194	197	203	199	201
Seed	22	23	25	25	23
Total food, seed, and industrial use	5,961	6,426	6,424	6,038	6,493
Food use[1]	1,348	1,384	1,400	1,372	1,347
Total domestic use	11,062	11,202	10,943	10,353	11,534
Percent food use of total domestic use	12%	12%	13%	13%	12%

[1]Food use was calculated by summing high-fructose corn syrup (HFCS), glucose and dextrose (sweeteners), starch, alcohol for beverages and manufacturing, and cereals and other products. Starch includes non-food uses such as drywall for building construction and alcohol for beverages and manufacturing also includes some non-food uses.

Table 3. U.S. barley domestic and food use for marketing years (Jun-May) 2009 to 2014.

	09/10	10/11	11/12	12/13	13/14
Food, alcohol, and industrial use	158.7	153.7	149.0	141.0	148.3
Seed use	5.0	4.8	6.0	5.8	4.9
Feed and residual use	47.0	49.8	36.6	66.2	66.1
Total domestic use	211	208	192	213	219
Percent food use of total domestic use[1]	75%	74%	78%	66%	68%

[1]Percent food use was calculated by dividing food, alcohol, and industrial use by total domestic use.

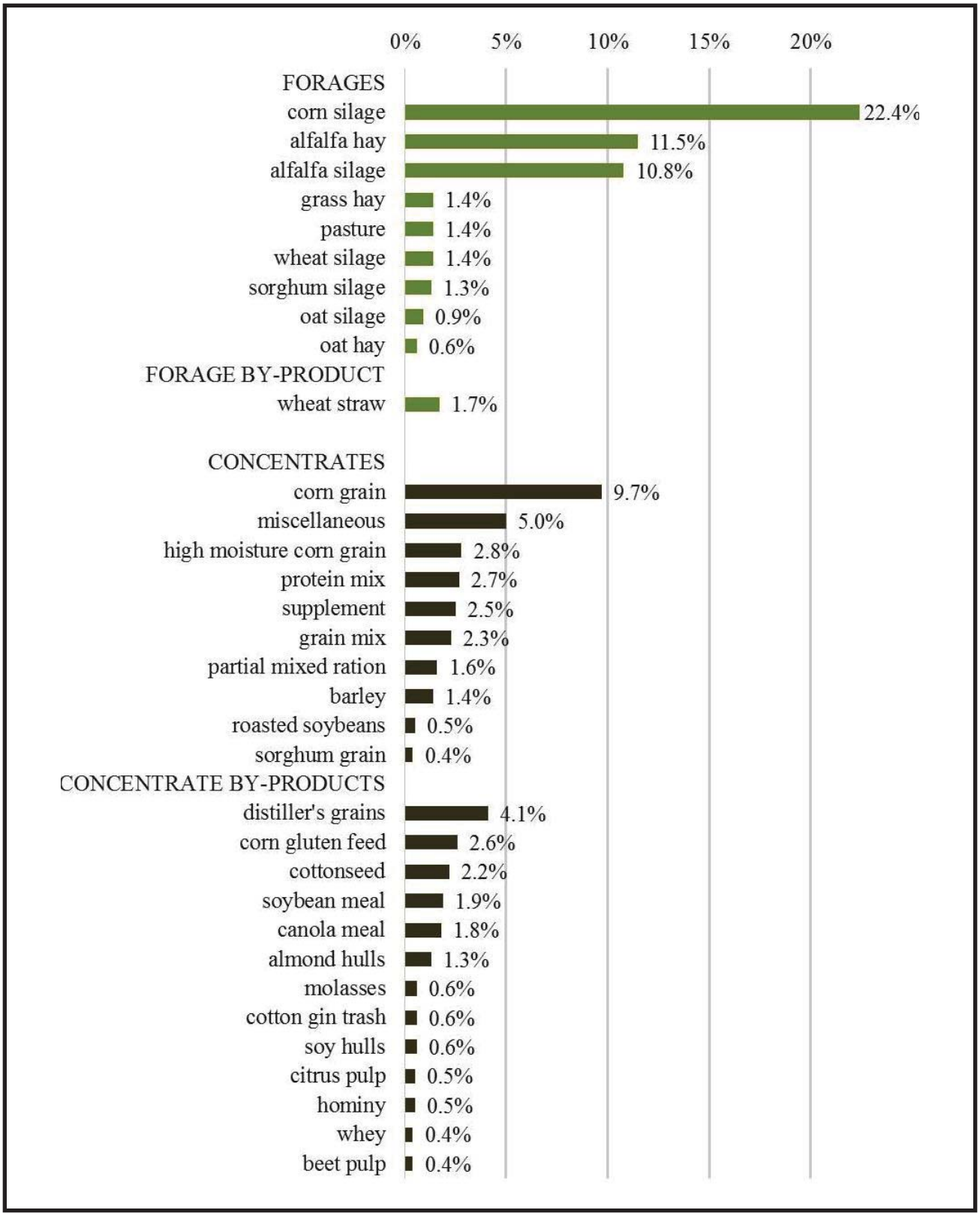

Figure 1. Composition of the national average dairy diet on a percent DM basis.

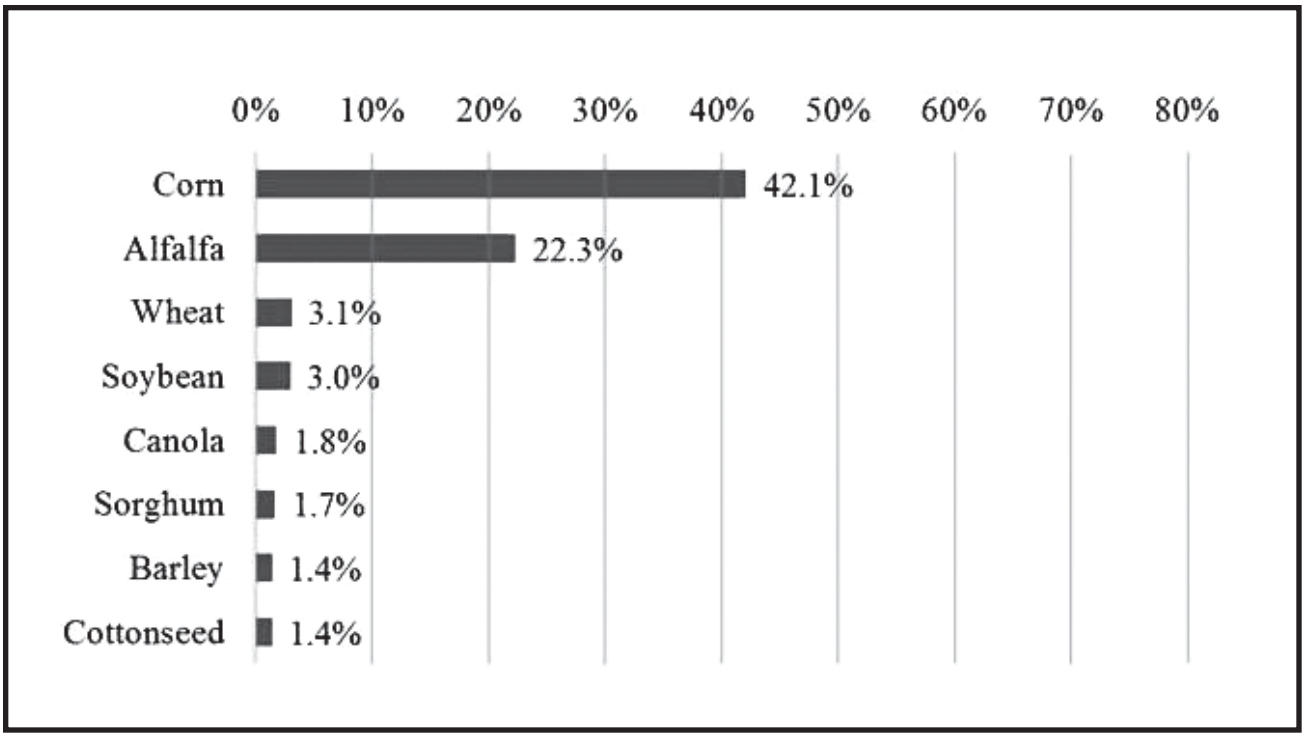

Figure 2. Contribution (DM basis) by the eight major crops supplying 80% of the DM in the national average dairy diet.

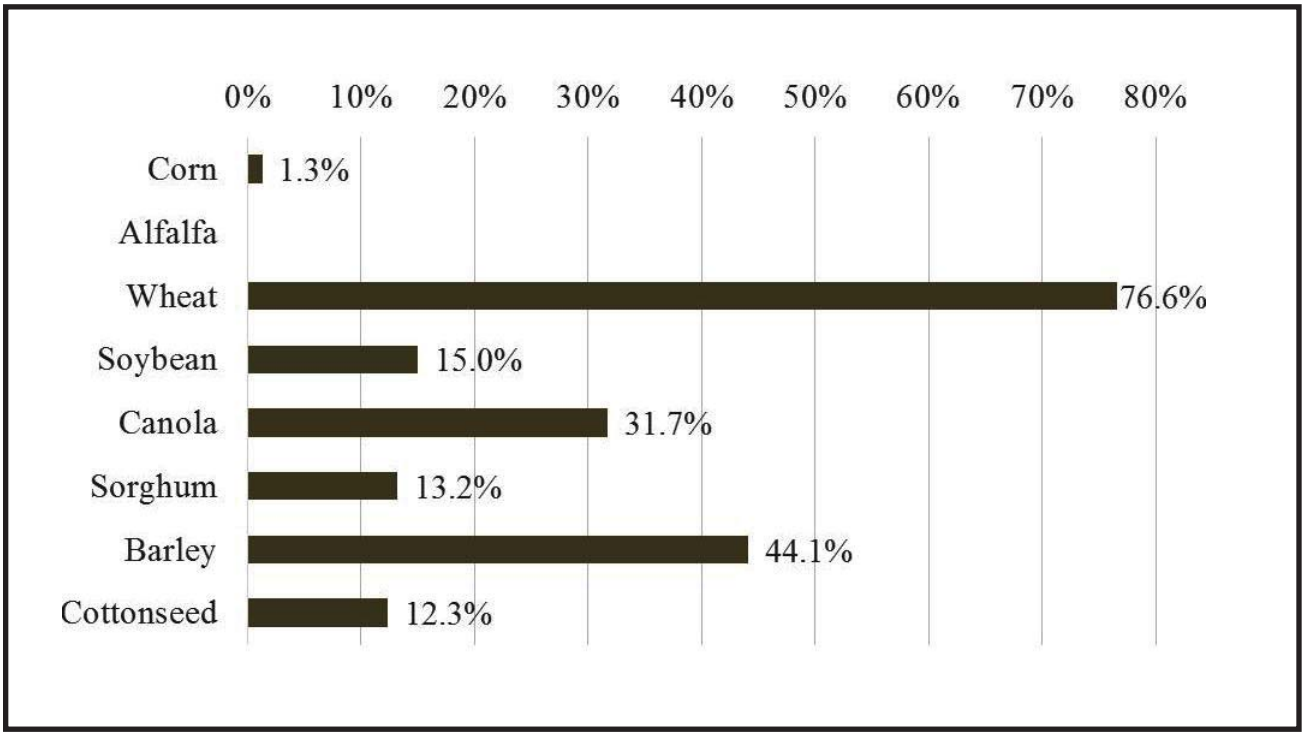

Figure 3. Percent food use of total domestic use for the 8 major crops in teh national average dairy diet.