By-Product Feedstuffs in Dairy Cattle Diets in the Upper Midwest

Randy D. Shaver, Ph.D.
Associate Professor, Extension Nutritionist
Department of Dairy Science,
College of Agricultural and Life Sciences
University of Wisconsin-Madison

Introduction

The purpose of this paper is to review by-product feedstuffs commonly used in dairy cattle diets in the Upper Midwest. Typical nutrient analyses of most of these feedstuffs are provided in the attached table. Otherwise the nutrient composition is listed in the text. Tabular listings of nutrient analyses are average values, and the variation in nutrient content of by-product feedstuffs is large. Laboratory testing of by-product feedstuffs for actual nutrient content is recommended.

The break-even costs discussed in the text were calculated using FEEDVAL4 (Howard and Shaver, 1993) with blood meal (undegraded intake protein; $475 per ton), urea (degraded intake protein; $300 per ton), shelled corn (energy; $2.25 per bushel), tallow (fat; $25 per cwt.), dicalcium phosphate (phosphorus; $18 per cwt.), and calcium carbonate (calcium; $7 per cwt.) as referee feedstuffs. These break-even costs are provided only for comparative purposes. Actual break-even costs vary as prices of the referee feedstuffs change. These change from month to month, year to year, supplier to supplier, and location to location. Calculation of relevant break-even prices is recommended. The FEEDVAL4 spreadsheet is available through county extension offices and can be purchased from Ag. Source Cooperative, Verona, WI.

Some general guidelines on upper feeding limits for by-product feedstuffs are provided. However, actual feeding rates should be determined through formulation of diets to meet specifications for neutral detergent fiber (NDF), nonfiber carbohydrate (NFC; primarily starch), fat, and ruminally undegraded (UIP) and degraded (DIP)intake protein.

High-Fiber Byproducts

Beet Pulp. Beet pulp (Feed Industry Red Book, 1994) is the dried residue from sugar beets which has been cleaned and freed from crowns, leaves and sand, and which has been extracted in the process of manufacturing sugar. Beet pulp with molasses includes the beet molasses obtained in the manufacture of sugar. Beet pulp is bulky and highly palatable. It may be fed dry or wet. It may be sold in either pelleted or meal form. Typical nutrient analyses are provided in the table. Upper feeding limits on beet pulp are about half of the grain concentrate or 8 to 15 lb. of dry matter (DM) per cow per day (Howard, Hoard's Dairyman, 1988). Beet pulp is often used to reduce the content of NFC in dairy cattle diets; beet pulp and shelled corn contain 39% and 75% NFC, respectively. Much of the NFC in beet pulp is pectin which has a propensity for acetate versus propionate production in the rumen. The NDF in beet pulp is highly fermentable in the rumen, and it can be used to supply fermentable fiber in the diet. Inclusion of beet

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pulp in early lactation diets allows the formulation of high NDF, moderate NFC diets of high energy density. Beet pulp is also used as a forage replacer. However, it has limited forage replacement value (Armentano and Clark, Hoard's Dairyman, 1992); effectiveness factor of .43 (fraction of NDF) versus 1.0 for forages. The upper limit on forage replacement is 15 to 25 percent of the forage dry matter in the diet.

Brewers Dried Grains. Brewers dried grains is defined (Feed Industry Red Book, 1994) as the dried extracted residue of barley malt alone or in mixture with other cereal grain or grain products resulting from the manufacture of wort or beer and may contain pulverized dried spent hops in an amount not to exceed 3%, evenly distributed. Typical nutrient analyses are provided in the table. Approximately 50% of the protein is ruminally undegraded compared with 35% in soybean meal. The higher fraction of ruminally undegraded protein relative to soybean meal makes brewers dried grains particularly attractive in diets for lactating dairy cows. Brewers dried grains are commonly used by the feed industry as a component of protein supplements for dairy cattle. The formula feed industry generally limits brewers dried grains to less than 50% of protein supplements and 25% of complete feeds for dairy cattle. Brewers dried grains are highly palatable. Upper feeding limits on brewers dried grains are 5 to 10 lb. of DM per cow per day (Howard, Hoard's Dairyman, 1988). Brewers dried grains have limited value as a source of ruminally undegraded protein in high corn silage diets because of their low lysine content. Brewers dried grains are often used to reduce the content of NFC in dairy cattle diets; brewers dried grains and shelled corn contain 17% and 75% NFC, respectively. Brewers dried grains are also used as a forage replacer. However, they have limited forage replacement value (Armentano and Clark, Hoard's Dairyman, 1992); effectiveness factor of .33 (fraction of NDF) versus 1.0 for forages. The upper limit on forage replacement is 10 to 15 percent of the forage dry matter in the diet.

Brewers Wet Grains. Brewers wet grains is defined (Feed Industry Red Book, 1994) as the extracted residue from the manufacture of wort from barley malt alone or in mixture with other cereal grains or grain products. The guaranteed analysis shall include the maximum moisture. Typical nutrient analyses are similar to brewers dried grains, except for moisture content which may range from 70 to 80 percent. The primary market for wet brewers grains is dairy farms and beef cattle feedlots in relatively close proximity to the brewery. The high moisture content of brewers wet grains limits its use to livestock operations near the point of production or within a few hundred miles of major breweries. Wet brewers grains are incorporated directly into rations at the farm. Feeding levels are generally in the range of 20 to 40 lb./cow/day (as fed basis) for dairy cattle. Precautions are generally taken to not increase dietary moisture content above 50 to 55 percent. Adding brewers wet grains to diets containing low-moisture haycrop silages (less than 50% moisture) may increase consumption of a total mixed ration (TMR). The supply should be turned every 7 to 10 days to keep brewers wet grains fresh and acceptable to livestock. This limits their use in small herds, but some suppliers avoid this problem by delivering brewers wet grains in silage bags which allows on-farm storage for a month or more without spoilage. Comments made in the section on brewers dried grains apply here as well

Corn gluten feed. Corn gluten feed (Feed Industry Red Book, 1994) is that part of commercial shelled corn that remains after the extraction of the larger portion of the

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starch, gluten and germ by the processes employed in the wet milling manufacture of corn starch or syrup. It may or may not contain fermented corn extractives and(or) corn germ meal. It may be fed dry or wet. It may be sold in either pelleted or meal form. Typical nutrient analyses are provided in the table. The old manufacturing process resulted in much higher calcium values than in current products because of the use of limestone for neutralization; calcium values in most feed tables are too high (Armentano, UW-Madison, personal comm.). Use the calcium value for shelled corn unless the corn gluten feed has been analyzed for calcium content. Wet corn gluten feed contains about 45 percent DM. Upper feeding limits on corn gluten feed are 12 to 15 lb. and 8 to 12 lb. of dry matter (DM) per cow per day for dry and wet corn gluten feed, respectively (Howard, Hoard's Dairyman, 1988). For wet corn gluten feed, feeding levels are generally in the range of 15 to 25 LB./cow/day (as fed basis). The supply should be turned every 7 to 10 days to keep wet corn gluten feed fresh and acceptable to livestock. This limits its use in small herds. The inclusion rate of corn gluten feed is often restricted because of its high content of soluble (50-55% of CP) and ruminally degraded protein (70-75% of CP). Relative to dry corn gluten feed, the wet product is on the high end of these ranges for content of soluble and ruminally degraded protein. The ruminally undegraded protein in corn gluten feed has limited value because of its low lysine content, particularly in high corn silage diets. Corn gluten feed is generally used as a grain replacer. Used in this manner it lowers the content of NFC in dairy cattle diets; corn gluten feed and shelled corn contain 20% and 75% NFC, respectively. Corn gluten feed is also used as a forage replacer (Armentano and Clark, Hoard's Dairyman, 1992); effectiveness factor of .56 (fraction of NDF) versus 1.0 for forages. The upper limit on forage replacement is 20 to 25 percent of the forage dry matter in the diet.

Cottonseeds. Whole cottonseed (Feed Industry Red Book, 1994) is the unprocessed and unadulterated oilseed which has been separated from the cotton fiber. Delinted cottonseed (Feed Industry Red Book, 1994) is the unprocessed and unadulterated oilseed which has been separated from the cotton fiber with less than 5 percent retained lint. Typical nutrient analyses are provided in the table. Cottonseeds are fed to high-producing dairy cows for a source of fat and highly-digestible fiber. They are also used as a forage replacer. Delinted cottonseed contains slightly more protein, fat and energy, but less fiber, than whole cottonseed. There are both mechanically and acid delinted cottonseed products. The mechanically delinted cottonseed is more palatable than acid delinted cottonseed, and is the preferred delinted product for dairy cows. Little difference in animal performance between whole cottonseed and mechanically delinted cottonseed has been reported (Coppock and Wilks, 1991). Upper feeding limits on cottonseeds are 6 to 7 lb. of DM per cow per day (Howard, Hoard's Dairyman, 1988). The inclusion rate of cottonseeds are often restricted because of their high fat content and the use of other high-fat ingredients in the diet. Precautions are generally taken to not supplement dietary fat from high-fat plant sources above 1.5 lb. per cow per day. Cottonseeds are often used as a grain replacer. Used in this manner they lower the content of NFC in dairy cattle diets; cottonseeds and shelled corn contain 8-10% and 75% NFC, respectively. Cottonseeds are an excellent forage replacer (Armentano and Clark, Hoard's Dairyman, 1992); effectiveness factor of 1.3 (fraction of NDF) versus 1.0 for forages. The upper limit on forage replacement is 25 to 35 percent of the forage dry

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matter in the diet. Relative to mechanically delinted cottonseed, whole cottonseed is on the high end of this range for replacement of dietary forage. Gossypol toxicity or adverse subclinical effects of gossypol on reproduction should not be a concern when no more than 15% cottonseed products (cottonseeds and cottonseed meal) are included in the total diet DM. Cottonseeds should be monitored for aflatoxin contamination. This is especially true for gin-run cottonseed that may be high in moisture content causing mold problems in storage. This cottonseed may be offered at a lower price, but may not be a good buy when potential storage problems and the higher moisture content are considered.

Distillers Dried Grains. Distillers dried grains (Feed Industry Red Book, 1994) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or grain mixture by separating the resultant coarse grain fraction of the whole stillage and drying by methods employed in the grain distilling industry. The predominant grain shall be declared as the first word in the name; barley, cereals, corn, rye, sorghum, and wheat. Typical nutrient analyses (DM basis) are 23% crude protein (CP), 17% acid detergent fiber (ADF), 43% NDF, and 9.8% ether extract (EE) (NRC, 1989). Approximately 55% of the protein is ruminally undegraded compared with 35% in soybean meal. The higher fraction of ruminally undegraded protein relative to soybean meal makes distillers dried grains particularly attractive in diets for lactating dairy cows. Distillers dried grains are commonly used by the feed industry as a component of protein supplements for dairy cattle. The formula feed industry generally limits distillers dried grains to less than 50% of protein supplements and 25% of complete feeds for dairy cattle. Distillers dried grains are highly palatable. Upper feeding limits on distillers dried grains are listed at 10 to 15 lb. of DM per cow per day (Howard, Hoard's Dairyman, 1988), but limits on daily intakes of 5 to 10 lb. of DM per cow are more common. The inclusion rate of distillers dried grains is often restricted because of its high fat content and the use of other high-fat ingredients in the diet. Precautions are generally taken to not supplement dietary fat from high-fat plant sources above 1.5 lb. per cow per day. Distillers dried grains have limited value as a source of ruminally undegraded protein in high corn silage diets because of their low lysine content. One quality concern with distillers dried grains is heat-damaged protein. Acid detergent insoluble nitrogen (ADIN) is the method typically used by forage testing laboratories to estimate heat-damaged protein. Distillers dried grains can be high in ADIN; ranging from 10 to 40 percent of CP (Chase, 1991). Poor performance by lactating dairy cows has been observed when feeding distillers dried grains containing 25% to 35% of the CP in the ADIN fraction. Finding some protein in the ADIN fraction is a normal occurrence in protein supplements that undergo heating during processing, and lower concentrations probably do not limit animal performance because a portion of the ADIN is digestible. Distillers dried grains are often used to reduce the NFC content of dairy cattle diets; distillers dried grains and shelled corn contain 16% and 75% NFC, respectively. Distillers dried grains are also used as a forage replacer. Their effectiveness factor is .76 versus 1.0 for forages (Armentano and Clark, Hoard's Dairyman, 1992). The upper limit on forage replacement is 20 to 30 percent of the forage dry matter in the diet.

Distillers Dried Grains With Solubles. Distillers dried grains with solubles (Feed Industry Red Book, 1994) is the product obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or grain mixture by condensing and drying at least three-fourths of the solids of the whole stillage by methods employed in the grain distilling industry. The predominant grain shall be declared as the first word in the name; barley, cereals, corn, rye, sorghum, and wheat. Typical nutrient analyses are provided in the table. Comments made in the section on distillers dried grains apply here as well.

Distillers Solubles. Distillers dried solubles (Feed Industry Red Book, 1994) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or grain mixture by condensing the thin stillage fraction and drying it by methods employed in the grain distilling industry. The predominant grain shall be declared as the first word in the name; barley, cereals, corn, rye, sorghum, and wheat. Typical nutrient analyses (DM basis) are 29.7% CP, 7% ADF, 23% NDF, and 9.2% EE (NRC, 1989). Most distilleries add the liquid solubles to the grains and do not produce dried solubles (Feed Industry Red Book, 1994). Condensed distillers solubles (Feed Industry Red Book, 1994) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or grain mixture by condensing the thin stillage fraction to a semi-solid. The predominant grain shall be declared as the first word in the name. Condensed distillers solubles can be marketed as a liquid feed ingredient. Contents of DM from 8 to 26% and CP from 30 to 35% (DM basis) for condensed distillers solubles have been reported in research trials (Chase, 1991). Michigan State workers found that condensed distillers solubles (8% DM) used as replacement for water at intakes up to 20% of total ration DM did not depress animal performance in finishing cattle (Chase, 1991). Cornell workers added condensed distillers solubles (26% DM) to rations for early lactation dairy cows at 0, 8, and 16% of total ration DM (Chase, 1991). Feed intake, milk production, and milk composition were similar for the three rations. Maximum daily intake of condensed distillers solubles was about 30 LB. per cow (8 LB. per cow of DM).

Distillers Wet Grains. Distillers wet grains is defined (Feed Industry Red Book, 1994) as the product obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or grain mixture. The guaranteed analysis shall include the maximum moisture. Typical nutrient analyses are similar to distillers dried grains, except for moisture. Feeding limits are similar to those for brewers wet grains. Comments made in the section on brewers wet grains apply here as well.

Hominy. The dry corn milling process is the modern way of preparing table corn meal; the process also produces hominy and corn grits and the useful by-products are hominy feed, corn bran, corn germ cake and corn germ meal (Feed Industry Red Book, 1994). Hominy feed is defined (Feed Industry Red Book, 1994) as a mixture of corn bran, corn germ and part of the starchy portion of either white or yellow corn kernels or mixture thereof, as produced in the manufacture of pearl hominy, hominy grits, or table meal, and must contain not less than 4 percent fat. Typical nutrient analyses are provided in the table. The fiber, starch and fat content of hominy feed can vary; laboratory analysis is recommended. Hominy feed is generally used as a grain replacer. It is similar to ear corn in content of fiber and nonfiber carbohydrates, but similar to shelled corn in energy value because of its higher fat content (7-8% vs. 3-4%). The physical form of hominy feed is fairly fine relative to corn that is typically processed on-farm, which enhances its energy value and content of ruminally fermentable carbohydrate.

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Upper feeding limits on hominy feed are 10 to 15 lb. of DM per cow per day (Howard, Hoard's Dairyman, 1988). The inclusion rate of hominy feed is often restricted because of its high fat content and the use of other high-fat ingredients in the diet. Precautions are generally taken to not supplement dietary fat from high-fat plant sources above 1.5 lb. per cow per day.

Malt Sprouts. Malt sprouts (Feed Industry Red Book, 1994) are obtained from malted barley by the removal of the rootlets and sprouts, which may include some of the malt hulls, other parts of malt, and foreign material unavoidably present. It must contain not less than 24% CP. The term "malt sprouts" when applied to the corresponding portion of other malted cereals must be used in qualified form, as, for example: "rye malt sprouts" and "wheat malt sprouts". Typical nutrient analyses are provided in the table. Malt sprouts are commonly used by the feed industry as a component of protein supplements for dairy cattle. Upper feeding limits on malts sprouts are the same as for brewers dried grains (Howard, Hoard's Dairyman, 1988). Malt sprouts are often used to reduce the NFC content of dairy cattle diets and as a forage replacer. However, they have limited forage replacement value (Armentano and Clark, Hoard's Dairyman, 1992); effectiveness factor of .48 versus 1.0 for forages. The upper limit on forage replacement is 15 to 25 percent of the forage dry matter in the diet.

Soy Hulls. Soybean hulls consist primarily of the outer covering of the soybean. Typical nutrient analyses are provided in the table. Upper feeding limits on soy hulls are 8 to 12 lb. of DM per cow per day (Howard, Hoard's Dairyman, 1988). Soy hulls are often used to reduce the content of NFC in dairy cattle diets; soy hulls and shelled corn contain 14% and 75% NFC, respectively. The NDF in soy hulls is highly fermentable in the rumen, and it can be used to supply fermentable fiber in the diet. Inclusion of soy hulls in early lactation diets allows the formulation of high NDF, moderate NFC diets of high energy density. Soy hulls have limited value as a forage replacer. Until more research is available, we have set the effectiveness factor at .25 (fraction of NDF) and the upper limit on forage replacement at 10 percent of the forage dry matter in the diet. The break-even cost is $70 per ton (as fed basis). Soybean mill feed (Feed Industry Red Book, 1994) is composed of soybean hulls and the offal from the tail of the mill which results from the manufacture of soy grits or flour. It must contain not less than 13.0% crude protein and not more than 32.0% crude fiber. The protein, fiber and fat content of soybean mill feed can vary; laboratory analysis is recommended. One product, soybean screenings, has a typical nutrient analyses (DM basis) of 30% CP, 20% ADF, 30% NDF, and 12% EE. This product can have a high percentage of weed seeds. Its inclusion rate is restricted to 5 to 10 lb. per cow per day because of its high fat content and the use of other high-fat ingredients in the diet. Precautions are generally taken to not supplement dietary fat from high-fat plant sources above 1.5 lb. per cow per day.

Wheat By-Products. Wheat bran (Feed Industry Red Book, 1994) is the coarse outer covering of the wheat kernel as separated from cleaned and scoured wheat in the usual process of commercial milling. Wheat middlings (Feed Industry Red Book, 1994) consist of fine particles of wheat bran, wheat shorts, wheat germ, wheat flour, and some of the offal from the tail of the mill. This product must be obtained in the usual process of commercial milling and must contain not more than 9.5% crude fiber. It may be sold in either pelleted or meal form. Typical nutrient analyses are provided in the table.

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Upper feeding limits on wheat bran and wheat middlings are 5 to 10 lb. and 10 to 15 lb. of DM per cow per day, respectively (Howard, Hoard's Dairyman, 1988). Wheat bran is palatable, mildly laxative and highly bulky making it fairly popular in concentrates for dry cows. The inclusion rate of wheat midds in milking cow diets are often restricted because of their high content of ruminally degraded protein (75% of CP). Wheat midds are generally used as a grain replacer. Used in this manner they lower the content of NFC in dairy cattle diets; wheat midds and shelled corn contain 35% and 75% NFC, respectively. Wheat midds are also used as a forage replacer (Armentano and Clark, Hoard's Dairyman, 1992); effectiveness factor of .57 (fraction of NDF) versus 1.0 for forages. The upper limit on forage replacement is 20 to 25 percent of the forage dry matter in the diet.

High-Protein Byproducts

Plant Sources

Canola Meal. Canola meal (Feed Industry Red Book, 1994) consists of the meal obtained after the removal of most of the oil, either by direct or prepress solvent extraction processes, from rapeseed (Brassica spp.), the oil component of which contains less than 2% erucic acid and the solid component of which contains less than 30 micromoles of glucosinolates per gram of air-dry, oil-free solid. It must contain a minimum of 35% protein, a maximum of 12% crude fiber, and a maximum of 30 micromoles of glucosinolates per gram. Typical nutrient analyses are provided in the table. Upper feeding limits for canola meal are 5 to 8 lb. of DM per cow per day. The inclusion rate of canola meal in milking cow diets is often restricted because of its high content of ruminally degraded protein (72% of CP).

Corn Gluten Meal. Corn gluten meal (Feed Industry Red Book, 1994) is the dried residue from corn after the removal of the larger part of the starch and germ, and the separation of the bran by the process employed in the wet milling manufacture of corn starch or syrup, or by enzymatic treatment of the endosperm. It may or may not contain fermented corn extractives and(or) corn germ meal. Both 60% and 40% CP products are often available. Typical nutrient analyses are provided in the table. Upper feeding limits on corn gluten meal are 2 to 3 lb. of DM per cow per day. Palatability may be a problem when fed in a protein topdress. Approximately 55% of the protein is ruminally undegraded compared with 35% in soybean meal. The higher fraction of ruminally undegraded protein relative to soybean meal makes corn gluten meal particularly attractive in diets for lactating dairy cows. Corn gluten meal is commonly used by the feed industry as a component of protein supplements for dairy cattle. The ruminally undegraded protein in corn gluten meal has limited value because of its low lysine content, particularly in high corn silage diets. However, corn gluten meal (60) is high in methionine and is often combined with high-lysine bypass protein supplements like animal-marine protein by-products and heat-treated soybean products in protein blends. As with distillers dried grains, high ADIN may also be a concern for corn gluten meal.

Cottonseed Meal. Cottonseed meal (Feed Industry Red Book, 1994) is the product obtained by finely grinding the flakes which remain after removal of most of the oil from cottonseed by a solvent extraction process (solvent-extracted meal) or by finely

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grinding the cake which remains after removal of most of the oil from cottonseed by a mechanical extraction process (mechanically-extracted meal). It must contain not less than 36% CP. Typical nutrient analyses are provided in the table. Its fiber content is higher (19% vs. 10% ADF) and energy content lower (.79 vs. .88 Mcal NEl/LB.) than soybean meal. There are no feeding limits for cottonseed meal (Howard, Hoard's Dairyman, 1988), but restrictions are generally imposed through formulation of diets to meet specifications for CP and UIP. Protein degradability is fairly high and similar to soybean meal (57% vs. 65%). Gossypol toxicity or adverse subclinical effects of gossypol on reproduction should not be a concern when no more than 15% cottonseed products (cottonseeds and cottonseed meal) are included in the total diet DM. This upper feeding limit should be monitored when both whole cottonseeds and cottonseed meal are fed.

Linseed Meal. Linseed meal (Feed Industry Red Book, 1994) is the product obtained by grinding the flakes which remain after the removal of most of the oil from flaxseed by a solvent extraction process (solvent-extracted meal) or by grinding the cake or chips which remain after removal of most of the oil from flaxseed by a mechanical extraction process (mechanically-extracted meal). Typical nutrient analyses are provided in the table. There are no feeding limits for linseed meal (Howard, Hoard's Dairyman, 1988), but restrictions are generally imposed through formulation of diets to meet specifications for CP and UIP. Protein degradability is high and similar to soybean meal (65%). Linseed meal is palatable and mildly laxative. Its fiber content is higher (19% vs. 10% ADF) and energy content lower (.81 vs. .88 Mcal NEl/LB.) than soybean meal.

Soybean Meal. Soybean meal (Feed Industry Red Book, 1994) is the product obtained by grinding the flakes which remain after removal of most of the oil from either whole or dehulled soybeans by a solvent extraction process (solvent extracted meals). The product resulting from whole soybeans must contain not more than 7.0% crude fiber and not more than 12.0% moisture. The product resulting from dehulled soybeans must contain not more than 3.5% crude fiber and not more than 12.0% moisture. Mechanically-extracted soybean meal (Feed Industry Red Book, 1994) is the product obtained by grinding the cake or chips which remain after removal of most of the oil from whole soybeans by a mechanical extraction process. It must contain not more than 7.0% crude fiber and not more than 12.0% moisture. Typical nutrient analyses are provided in the table. Meals resulting from whole and dehulled soybeans contain 44% and 48% CP (as fed basis), respectively. Mechanically-extracted (expeller) meals contain more fat than solvent-extracted meals. Expeller meals are also higher in ruminally undegraded protein than solvent-extracted meals (55% vs. 35% UIP-CP). The CP content of soybean meal and its ruminal degradability are highly variable. The higher fraction of ruminally undegraded protein makes heat-processed soybean meal particularly attractive in diets for lactating dairy cows. The ruminally undegraded protein in heat-processed soybean meal has high value because of its high lysine content. There are no feeding limits for soybean meal (Howard, Hoard's Dairyman, 1988), but restrictions are generally imposed through formulation of diets to meet specifications for CP and UIP.

Soybeans. Most soybeans are processed to remove the oil for use as edible fats. The defatted by-product, soybean meal, is the most widely used protein concentrate in the animal feed industry. Full-fat soybeans are often used as a fat and protein supplement

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for milking cows by dairy producers in soybean cropping areas. Typical nutrient analyses are provided in the table. Relative to soybean meal, soybeans are lower in CP (42% vs. 50-55%), but heat-processed soybeans are higher in ruminally undegraded protein (50% vs. 35% UIP-CP). The ruminally undegraded protein content of raw soybeans is lower at 25% of CP. The ruminal degradability of the protein in soybeans is highly variable. Soybeans contain 18% to 20% fat. The inclusion rate of soybeans are often restricted because of their high fat content and the use of other high-fat ingredients in the diet. Precautions are generally taken to not supplement dietary fat from high-fat plant sources above 1.5 lb. per cow per day. This limits consumption of soybeans to less than 7 lb. of DM per cow per day. Raw soybeans are generally limited to less than 3 to 4 lb. of DM per cow per day because of their high ruminal protein degradability and potential detrimental effects of trypsin inhibitor on protein digestion in the small intestine. Lower restrictions are often imposed through formulation of diets to meet specifications for UIP. It is generally recommended that soybeans be rolled or cracked prior to feeding. The higher fraction of ruminally undegraded protein relative to soybean meal and raw soybeans makes heat-processed soybeans particularly attractive in diets for lactating dairy cows. The ruminally undegraded protein in heat-processed soybeans has high value because of its high lysine content. Roasting and extrusion are the two common methods of heat treatment. Roasted soybeans are passed through a flame. In a drum roaster soybeans fall through a flame as they move through a rotating drum. Popping exposes soybeans beans to dry heat; transit time may be controlled by a conveyor system. It is becoming more popular to steep the soybeans after roasting or popping. Satter and co-workers (1993) recommend that soybeans should be heated to 295 degrees F and then steeped for 30 minutes for proper treatment. This helps ensure a high UIP value and reduces its variability. Proper heat-treatment also eliminates concern about the anti-nutritional factors, trypsin inhibitor and urease and lipase-like enzymes, found in raw soybeans. Satter and co-workers (1993) also recommend using the protein dispersibility index (PDI) to evaluate the quality of roasted soybeans. It is recommended that soybeans be roasted to a PDI of 9 to 11. A PDI of 11 to 13 indicates a marginally low UIP value. A PDI of 13 to 15 suggests that soybeans have been under roasted. Extruded soybeans pass through a machine with a spiral, tapered screw that forces them through a tapered head. In the process the soybeans are ground and heated, producing a ribbon-like product. This releases the free oil from the soybean, which is the primary difference between unground roasted soybeans and extruded soybeans. This may lead to milkfat test depression when extruded soybeans are fed at more than 3 to 4 lb. of DM per cow per day.

Sunflower Meal. Sunflower meal (Feed Industry Red Book, 1994) is obtained by grinding the residue remaining after extraction of most of the oil from either whole or dehulled sunflower seed by either solvent (solvent-extracted meal) or mechanical extraction (mechanically-extracted meal) processes. Typical nutrient analyses are provided in the table. Dehulled sunflower meal contains more fiber (15% vs. 10% ADF) and less energy (.67 vs. .88 Mcal NEl/LB.) than soybean meal. Sunflower meal with hulls is lower in protein (26% vs. 45-50% CP) and energy (.60 vs. .67 Mcal NEl/LB.) and higher in fiber (33% vs. 15% ADF) than dehulled sunflower meal. There are no feeding limits for dehulled sunflower meal (Howard, Hoard's Dairyman, 1988), but restrictions

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are generally imposed through formulation of diets to meet specifications for CP and UIP. The inclusion rate of sunflower meal in milking cow diets is often restricted because of its high content of ruminally degraded protein (74% of CP). Upper feeding limits on sunflower meal with hulls is 5 to 8 lb. of DM per cow per day (Howard, Hoard's Dairyman, 1988). The hulls in sunflower meal are low in digestibility. This restricts the energy value of sunflower meal with hulls, and thus its feeding rate. However, this gives it some value as a forage replacer; the upper limit on forage replacement value of sunflower meal with hulls is 10 to 15 percent of the forage dry matter in the diet

Animal-Marine Sources

Animal-marine protein by-products are defined in the 1994 Feed Industry Red Book as follows:

Blood Meal. Blood meal is produced from clean, fresh animal blood, exclusive of all extraneous material such as hair, stomach belchings, and urine except in such traces as might occur unavoidably in good manufacturing processes. Types of blood include conventional cooker dried, flash dried, and spray dried. Spray drying produces a product that readily takes up and retains moisture and is not suitable for feed use. Cooker drying is an older process that has been used for many years, but the results are not uniform. Flash drying is a newer process which produces a product uniform in color with a high lysine content (about 9 percent of CP).

Hydrolyzed Feather Meal. Product resulting from the treatment under pressure of clean, undecomposed feathers from slaughtered poultry, free of additives and(or) accelerators. Not less than 75 percent of CP must be digestible as measured by the pepsin digestibility method.

Fish Meal. Fish meal is the clean, dried, ground tissue of undecomposed whole fish or fish cuttings, either or both, with or without the extraction of part of the oil.

Meat and Bone Meal. Meat and bone meal is the rendered product from mammal tissues, including bone, exclusive of blood, hair, hoof, horn, hide trimmings, manure, stomach and rumen contents, except in such amounts as may occur unavoidably in good processing practices. It shall contain a minimum of 4 percent phosphorus and the calcium level shall not be more than 2.2 times the actual phosphorus level. It shall not contain more than 14% pepsin indigestible residue and not more than 11% of the CP in the product shall be pepsin indigestible. The label shall include guarantees for minimum crude protein, minimum crude fat, maximum crude fiber, and minimum phosphorus. Meat meal is defined the same as meat and bone meal except that no minimum phosphorus level is required.

Poultry By-Product Meal. Poultry by-product meal consists of the ground, rendered, clean parts of the carcass of slaughtered poultry, such as necks, feet, undeveloped eggs, and intestines, exclusive of feathers, except in such amounts as might occur unavoidably in good processing practices. The label shall include guarantees for minimum crude protein, minimum crude fat, maximum crude fiber, and minimum phosphorus. The calcium level shall not exceed the actual level by more than 2.2 times.

Typical nutrient analyses of animal-marine protein by-products are provided in the table. Animal-marine protein by-products are concentrated sources of protein ranging from 54% to 90% CP (DM basis). They are also high in ruminally undegraded

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protein ranging from 50% to 80% of CP. The CP content of animal-marine protein by-products and their ruminal degradability are highly variable. The higher fraction of ruminally undegraded protein relative to soybean meal makes animal-marine protein by-products particularly attractive in diets for lactating dairy cows. The ruminally undegraded protein in blood meal and fish meal has high value because of its high lysine content. Fish meal is also high in methionine. Fish meal has an amino acid profile close to that believed to be required for milk production. The ruminally undegraded protein in meat and bone meal and poultry by-product meal is relatively high in lysine. Although feather meal has a relatively poor balance of amino acids, particularly lysine and methionine, it is a good source of sulfur and sulfur amino acids because of its high cystine content. This high content of cystine may conserve some of the methionine in the ration making the amino acid profile of feather meal appear more favorable, but research is needed. Fish meal, meat and bone meal, and poultry by-product meal are high in calcium and phosphorus. Because the relative biological availabilities of calcium and phosphorus are good, supplemental inorganic mineral needs are reduced when these ingredients are fed.

One of the major concerns about using animal-marine protein by-products as feed ingredients is their quality and nutrient consistency. Variation in nutritive value of animal-marine protein by-products is related to variation in source of raw materials available to rendering operations and(or) processing conditions such as pressure, temperature, and cooling time at different locations and at different times. For example, the ruminally undegraded protein content of fish meal can vary from 30 to 70 percent depending on processing conditions. These include the length of time the raw fish are stored before processing, type of dryer used, duration of heating, and extent of solubles add-back. Another concern is the variability in content of digestible protein in hydrolyzed feather meal. Research also shows that ruminal protein degradability and post-ruminal protein digestibility of meat and bone meal are highly variable. The calcium and phosphorus content of meat and bone meal are highly variable. Purchase ingredients from reputable suppliers of animal-marine protein by-products or feed dealers who are willing to assure minimum quality standards. Laboratory tests need to be developed and implemented to evaluate protein degradability of animal-marine protein by-products in the field. Meat and bone meal must be stored and handled properly to avoid problems with salmonella contamination. Meat and bone meal should be stored in a clean, dry bin or container covered to prevent contact with dogs, cats, rodents, and birds.

Typical feeding rates for blood meal, hydrolyzed feather meal, fish meal, meat and bone meal, and poultry by-product meal are .5-1.0, 1.0-1.5, 1.0-1.5, 1.0-2.0, and 1.0-1.5 pounds per cow per day, respectively. Lower restrictions are often imposed because of problems with palatability. Feeding animal-marine protein by-products as a topdress is difficult. Blending animal-marine protein by-products with the grain or forage at the time of feeding can help alleviate palatability problems. Animal-marine protein by-products can be mixed at about ten percent of the protein concentrate with reasonable palatability of the topdress. Even at this low inclusion rate cows should be adapted to animal-marine protein by-products gradually, and molasses addition to the protein concentrate may improve its palatability. Inclusion of animal-marine protein by-products into a TMR

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must also be done gradually to prevent depression of intake of the TMR. Monitor TMR intakes of fresh cows closely when feeding animal-marine protein by-products.

Unusual By-Product Feedstuffs

This section was adapted from a Western Regional Extension publication (Bath and co-workers, 1982) and the Proceedings of the Dairy Feeding Systems Symposium (Adams, 1990).

Bakery Wastes. Stale bread and other pastry products from stores or bakeries can be fed to dairy cattle in limited amounts. These products are sometimes fed as received without drying or even removal of the wrappers. They may be run through a forage chopper to facilitate feeding. Some distributors and dairy producers dry and grind the material for inclusion into a concentrate or TMR. The feeding rate of bakery wastes must be limited to avoid milkfat test depression, because they are relatively high in cooked starch. The upper feeding limit for dried bread is 20% of concentrate DM and 10% of TMR DM. Higher levels may be fed to replacement heifers and dry cows. For bakery wastes that are relatively high in fat (i.e. donuts at 25% fat), the feeding rate should be limited so that no more than one 1 LB. of added fat per cow per day is consumed. This level may need to be reduced if other sources of non-rumen inert fat are included in the diet. Dried bakery product is a fairly standardized ingredient used by the feed industry. It generally consists of a mixture of bread, cookies, cake, crackers, flours and doughs. Typical nutrient analyses (DM basis) for dried bakery products and dried bread are 12% CP, 3% ADF, .94 Mcal NEl/LB., .10% calcium, .22% phosphorus, and 12.7% EE and 11.7% CP, 4% ADF, .90 Mcal NEl/LB., .07% calcium, .26% phosphorus, and 10% EE, respectively.

Beans. Cull dried beans or peas contain about 25% CP (DM basis). They may comprise up to 15-20% of concentrate DM or 7-10% of TMR DM. Palatability and protein quality restrict their use to these levels. It is generally recommended that they be rolled prior to feeding. An anti-nutritional component of raw navy beans, lectins, reduces nutrient absorption in the small intestine and limits their feeding rate to less than 2 LB. per cow per day. Typical nutrient analyses (DM basis) for dried navy beans are 24% CP, 8% ADF, .88 Mcal NEl/LB., .15% calcium, .59% phosphorus, and 1.4% EE. Raw beans are high in content of ruminally degraded protein (70-80% of CP). Heat processing will minimize the detrimental effects of lectins on nutrient digestion and increase the UIP value of beans.

Corn Screenings. Corn screenings are normally similar to shelled corn in nutrient content. They are generally fine enough so that no additional processing is necessary. They often sell for less than corn or hominy. Corn screenings should be tested for mycotoxins because these toxins tend to associate with the fines when mold problems exist in corn. Vomatoxin is an indicator of mycotoxin contamination.

Candy. Candy products are available through a number of distributors and sometimes directly from smaller plants. They are often economical sources of nutrients, particularly fat. They may be high in sugar and(or) fat content. Milk chocolate and candy may contain 48% and 22% fat, respectively. They are sometimes fed in their wrappers. Candies, such as cull gummy bears, lemon drops or gum drops, are high in sugar content. Several ingredient firms that handle food processing wastes produce

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blends of candy or chocolate with other ingredients, such as pasta or peanut skins. These are generally standardized to a certain content of protein and fat. Typical nutrient analyses (DM basis) for candy, blended candy products, and chocolate are 5.2% CP, 5% ADF, 1.10 Mcal NEl/LB., .07% calcium, .17% phosphorus, and 22.4% EE, 13.0% CP, 12.1% ADF, 1.07 Mcal NEl/LB., .13% calcium, .20% phosphorus, and 17% EE, and 12.9% CP, 4% ADF, 1.30 Mcal NEl/LB., .07% calcium, .17% phosphorus, and 48.7% EE, respectively. The upper feeding limits for candy or candy blends and chocolate are 5 and 2 lb. per cow per day, respectively. This is approximately 15% of concentrate DM or 10% of TMR DM for candy and candy blends and 6% of concentrate DM or 4% of TMR DM for chocolate. The feeding rate of high-sugar candies should be limited to 2 to 4 lb. per cow per day.

Fat. Commonly used fat sources include whole oilseeds, animal fat, and various ruminally-inert granular fat products. Most herds supplementing fat are using a combination approach with whole oilseeds and animal fat. Intake of supplemental fat from whole oilseeds should be limited to about 1.5 lb. per cow per day or 3% of TMR DM. This limits intake of whole oilseeds to less than 7 lb. of DM per cow per day or 15% of TMR DM. Additional supplemental fat should come from a source relatively insoluble or inert in the rumen, such as animal fat or granular fats, depending upon handling, feeding, palatability and cost considerations. Many herds have experienced good success feeding animal fat at 2% of ration DM (about a pound per cow per day) to high producing cows along with whole oilseeds. Feeding guidelines for choice white grease are similar to those for tallow. Restaurant grease is not recommended for lactating dairy cows because of concerns about milkfat test depression related to trans fatty acids found in hydrogenated vegetable oils. Because the fatty acid profile of vegetable oil is more highly unsaturated than animal fat, its feeding rate should be limited to .5 LB. per cow per day and it should not be fed along with whole oilseeds. Total supplemental fat should be limited to less than 5% of ration DM (3% from whole oilseeds and 2% from animal fat) or less than 2.5 lb. per cow per day. This limits total ration fat levels to less than 7 to 8% of ration DM. Animal fat must be melted and can be difficult to blend in the TMR or feed individually in tie-stall barns. Blending tallow with the grain or other low fiber ingredients prior to or as it is being added to the TMR is recommended, particularly for tumble type mixers. Some companies have used insulated heating tanks and bulk delivery to make direct on-farm use of animal fat more cost effective and feasible. Blending animal fat with the protein concentrate or grain mix at the feed mill or purchasing commercial high-fat supplements can make it easier to feed animal fat. Diluting animal fat with other feed ingredients and adapting cows gradually to the fat may help alleviate palatability problems. Feeding animal fat in a TMR helps reduce consumption problems, but adapting cows gradually to the fat is still a good practice. The energy value of fat is listed at 2.65 Mcal NEl per LB. in the Dairy NRC (1989). Fat can be fed during the lactation period as long as level of milk production (>70 lb. per day) and body condition (BCS<3.0) warrant its use.

Liquid Whey. Because this by-product of cheese manufacture presents a disposal problem for many cheese plants, it is often delivered to dairy farms free of charge or for a small transportation fee. Liquid whey consists primarily of lactose, protein, minerals and water. Most liquid wheys contain only 4 to 7 percent dry matter,

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but the solids fraction is relatively high in feeding value. Sometimes a condensed or higher solids whey is provided. Whey has a variable protein content ranging from 9% to 30% CP (DM basis). However, most wheys contain 11% to 13% CP (DM basis) and have an energy value close to ear corn. Some wheys contain 7% to 8% fat, but most contain only .2% to 1% fat (DM basis). Typical nutrient analyses (DM basis) for liquid whey are provided in the table. It is important to have an expected nutrient analyses provided by the plant, and it is recommended that the delivered material be tested periodically. Whey is best provided using a tank or watering device. Frost-free, low energy waterers may be used to provide whey under pressure or gravity feed. This method minimizes fly problems. Air or another agitation system should be used to prevent the solids from settling out before the whey is consumed. Both sweet whey from hard cheese manufacture and acid whey from cottage cheese manufacture are available. Both reach a low pH of 3 to 4 shortly after delivery which keeps spoilage problems to a minimum. Plastic lines and valves should be used when piping stall barns for feeding whey through drinking cups. Holstein cows usually will drink 80 to 100 LB. per day of low-solids whey when it is offered free-choice. This may reduce forage consumption if adjustments are not made in concentrate feeding. It is recommended that the ration be balanced and the amount of concentrate and its nutrient specifications be adjusted according to the nutrients provided by the whey. Whey should be treated as a wet concentrate in ration formulation. Generally, few problems are encountered when feeding liquid whey to dairy cattle. However, bloat or acidosis and even death may occur if the supply is allowed to run out and hungry animals over-consume whey in a short time. Whey should be available at least 18 to 20 hours daily. It is important that animals fed liquid whey are allowed access to water. They may reduce water consumption on their own, but water must be available at all times. However, it may be necessary in some cases to restrict water intake for 5 to 10 hours each day for several days when initially starting to feed whey to encourage cows to drink it. It is recommended that intakes of liquid whey be limited to not more than 100 to 150 LB. per cow per day. Liquid whey can also be used in feeding programs for replacement heifers.

Nuts. Peanuts, cashews, and various nuts or nut mixtures are sometimes available from processors. Most contain 18% to 27% CP and 45% to 65% fat (as fed basis). This high fat content restricts their use to less than 2 to 3 LB. per cow per day. Nuts and nut mixtures should be analyzed frequently, particularly for fat and protein content, because the different kinds and mixtures are highly variable.

Pasta. Available from pasta plants and some ingredient distributors as straight pasta or in blends with other ingredients, such as candy. Pasta must be used in limited amounts to avoid depression of milkfat test, because it is mostly starch. It does not have as much of a propensity for depression of milkfat test as cooked starch or bread. Typical nutrient analyses (DM basis) for pasta are 14.6% CP, 3% ADF, .90 Mcal NEl/LB., .02% calcium, .16% phosphorus, and 1.6% EE. Pasta can be fed at up to 4 to 8 LB. of DM per cow per day depending on the starch content of the diet.

Peanut Skins. Peanut skins are available from ingredient suppliers either straight or in blends with other ingredients. Typical nutrient analyses (DM basis) for peanut skins are 17.4% CP, 16.3% ADF, .68 Mcal NEl/LB., .16% calcium, .07% phosphorus, and 26% EE. The protein is poorly digested and should be discounted by

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half when formulating rations. Peanut skins have a low energy value despite their high fat content, because of poor digestibility. Peanut skins should be limited to less than 15% of concentrate DM or 7% of TMR DM, because of their poor palatability and high fat content.

Potato Waste. Potato waste is available in potato processing areas, and includes cull potatoes, french fries and potato chips. Cull fresh potatoes that are not frozen, rotten, or sprouted can be fed to cows either whole or chopped. Potato waste straight from a processing plant may contain varying amounts of inedible or rotten potatoes, french fries or chips, skins, and fats or oils from frying operations. Potato waste usually contains 75% to 80% moisture. It should be treated as a wet, starchy concentrate in ration formulation, and limited to not more than 25 to 35 LB. as fed or 5 to 8 LB. of DM per cow per day. Typical nutrient analyses (DM basis) for cull potatoes and potato waste are 10% CP, 3% ADF, .83 Mcal NEl/LB., .02% calcium, .24% phosphorus, and .4% EE and 8% CP, 6% ADF, .87 Mcal NEl/LB., .16% calcium, .25% phosphorus, and 5% EE, respectively.

Snap Bean Cannery Waste. Typical nutrient analyses (DM basis) for snap bean cannery waste are 10% DM, 23.5% CP, 17% ADF, .75 Mcal NEl/LB., and 3% EE. It can be used to replace some of the hay or silage in the ration. However, it should be limited to not more than 30 to 40 LB. as fed per cow per day because of its high moisture content. Storage life in piles probably does not exceed a few days to prevent heating and spoilage.

Soy Cakes. Soy cakes are a by-product of the production of soy sauce. Typical nutrient analyses (DM basis) for soy cakes are 70-75% DM, 27-30% CP, 15-20% ADF, .90-.95 Mcal NEl/LB., .60-.70% calcium, .15-.20% phosphorus, and 10% EE. Soy cakes contain 8% to 10% salt. This limits their use to not more than 5 LB. as fed per cow per day. No additional salt is needed in the diet when soy cakes are fed at their upper limit, but cows can be allowed access to free-choice salt. Supplemental trace minerals will need to be provided from another source if previously provided from trace-mineralized salt. Soy cakes should not be fed to dry cows, because of concerns about causing udder edema. It is recommended that the salt content of soy cakes be checked periodically. Soy cakes resulting from the production of low-sodium soy sauce will be lower in salt content. More supplemental salt will need to be included in the diet when this type of product is fed. Soy cakes with a low salt content may undergo excessive heating in storage and have a shorter storage life due to their high moisture content.

Starch. Unheated starch is available from some candy manufacturers and sometimes may contain pieces of candy. Typical nutrient analyses (DM basis) for waste starch are 10.8% CP, 4.4% ADF, .85 Mcal NEl/LB., .13% calcium, .18% phosphorus, and .4% EE. It may comprise up to 15-20% of concentrate DM or 7-10% of TMR DM depending on the starch content of the diet. It is most effective when used in rations needing more rumen fermentable starch.

Sunflower Seeds. Typical nutrient analyses (DM basis) for oilseed and confectionery varieties are 19.6% CP, 16.5% ADF, 1.38 Mcal NEl/LB., .26% calcium, .67% phosphorus, and 44% EE and 23.5% CP, 28.5% ADF, .97 Mcal NEl/LB., .30% calcium, .60% phosphorus, and 25% EE, respectively. Oilseed varieties comprise about 95 percent of all sunflowers grown in the U.S. Intake of supplemental fat from whole

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oilseeds should be limited to about 1.5 lb. per cow per day or 3% of TMR DM. This limits intake of oilseed sunflower varieties to less than 3.5 LB. of DM per cow per day or 7% of TMR DM. The limit on confectionery sunflower varieties is 6 LB. of DM per cow per day or 12% of TMR DM. Sunflower seeds can be fed whole without any processing. Research trials at South Dakota State University (Schingoethe, 1992) showed no advantage to rolling or cracking sunflower seeds. There are no palatability problems when sunflower seeds are fed in TMRs. However, cows may not readily consume sunflower seeds when topdressed or fed separately from other ration ingredients. Sunflower seeds have some value as a forage replacer; the upper limit on forage replacement value of sunflower seeds is 5 to 10 percent of the forage dry matter in the diet. The low digestibility of the fiber in sunflower seeds relative to whole cottonseeds is a disadvantage of sunflowers.

Sweet Corn Cannery Waste. Sweet corn cannery waste results from sweet corn that is canned or frozen. Cannery waste consists primarily of husks, cobs, cull ears, and missed kernels. The feeding value on a dry matter basis of cannery waste is about the same as poorly-eared field-corn silage. The primary difference being its moisture content, which is about 75-80 percent. Its nutrient composition is highly variable and periodic testing is recommended. It is generally stored as silage in bunker or trench silos. It works best in rations for low producing cows, dry cows and older replacement heifers, because its high moisture and acid content may limit intake of high producing cows. It can be used to replace some of the hay or silage in the ration, but it should be limited to not more than 25 to 35 LB. as fed per cow per day because of its variable nutrient composition and high moisture and acid content.

Vegetable Tops and Trims. These are available from vegetable processing and packaging plants. They consist primarily of carrot and beet tops, spinach, celery, and outer leaves of lettuce and cabbage. Most contain 15% to 30% CP and 10% to 20% ADF (DM basis). They are usually fed fresh but sometimes are ensiled mixed with other forages. Storage life in piles probably does not exceed a few days to prevent heating and spoilage. They should be analyzed for nutrient content periodically and whenever there is an obvious change in the material. They should be treated like wet (85-95% moisture) forages when formulating rations because of their large particle size, high ash content, and estimated energy content (.62-.68 Mcal NEl/LB. of DM).

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