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Feed & Forage Analysis Definitions

Proximate Analysis: A chemical scheme for evaluating feedstuffs, in which a feed is partitioned into the six fractions: 1) Moisture; 2) Total (Crude) Protein; 3) Fat; 4) Ash; 5) Crude Fiber; and 6) Nitrogen-Free Extract (NFE).

Inductively Coupled Plasma Discharge (ICP): The leading spectrochemical excitation source for atomic emission spectroscopy and ion source for inorganic mass spectrometry.

Near Infrared Reflective (NIR): NIR analysis is a non-destructive analytical technique for fast evaluation of the chemical composition and associated feeding value attributes of forages. Each major feed component exhibits unique absorption and reflectance characteristic patterns when near infrared energy is applied. These patterns are compared with standard NIR patterns stored in the computer's memory. NIR reports Moisture, Soluble Protein, Crude Protein, ADF, NDF, Heat Damaged Protein, Lignin, and Starch. From these, DM, Insoluble Protein, TDN, NEL, NEG, NEM, and ME can be calculated. It provides accurate results, fast turnaround time, reliability, and low cost.

E.L.I.S.A: Enzyme Linked ImmunoSorbant Assay

Relative Feed Value (RFV): A measure of a forage's feeding value compared to standards of full-bloom alfalfa-grass mixtures expressed as a percentage. A high RFV reflects high quality, high intake, high digestibility, and good animal performance. As an example, high producing dairy cows require forages with RFVs above 118.

Grass & Leg RFV =	(DMI * DDM) / 1.29
Legume RFV =	(DMI * DDM) / 1.29
Grass RFV =	(DMI * DDM) / 1.29

Dry Matter Intake (DMI):

Grass & Leg DRYMI =	120 / NDF
Legume DRYMI =	120 / NDF
Grass DRYMI =	120 / NDF

Digestible Dry Matter (DDM): Is the estimated digestibility of the feed based on the ADF concentration.

Grass & Leg DDM =	88.90 – (0.779 * ADF)
Legume DDM =	88.90 – (0.779 * ADF)

MOISTURE

Air Dry: This refers to feed that is dried by means of natural air movement, usually in the open. It may either be an actual or an assumed dry matter content; the later is approximately 90%. Most feeds are fed in an air-dry state.

As Fed: This refers to feed as normally fed to animals. It may range from 0 - 100% dry matter.

Moisture: The amount of water in the sample.

Dry Matter Basis: A method of expressing the level of a nutrient contained in a feed on the basis that the material contains no water.

Dry Matter (DM): That part of a feed which is not water. It is computed by determining the percentage of water and subtracting the water content from 100%.

DM% = (100% – Moisture%)

Anhydrous: The same as dry matter. What is left after the water is taken out.

Anhydrous% = (100% – Moisture%)

PROTEIN

Crude Protein (CP): The total amount of protein present, including true protein and non-protein nitrogen. Crude protein is determined by finding the nitrogen content and multiplying the result by 6.25. The nitrogen content of proteins averages about 16% (100 / 16 = 6.25).

Heat Damaged Protein: Heat Damaged Protein is the same value expressed as Acid Detergent Insoluble Nitrogen (ADIN), Acid Detergent Fiber Crude Protein (ADFCP), Acid Detergent Insoluble Crude Protein (AD-ICP), Indigestible ADF Crude Protein (IADFCP), or as "Unavailable Protein." It is an indication of the amount of heating that took place after harvest. Research suggests that a feedstuff is not truly heat damaged unless the protein contained in the Acid Detergent Fiber is both greater than 1% of the dry matter and greater than 10% of the total protein content of the feed. These "normalized" ADF Protein results are due to residual analysis error, intrinsic protein characteristics of the feed, and other reasons. Thus, those feeds which contain less than 1% ADF Protein or less than 10% of the crude protein in the ADF fraction should generally not be considered heat damaged.

Forages IADFCP = (.7 * ADFCP) Concentrates IADFCP = (.4 * ADFCP)

Acid Detergent Insoluble Nitrogen (ADIN): See Heat Damaged Protein.

Acid Detergent Insoluble Crude Protein (AD-ICP): See Heat Damaged Protein.

Acid Detergent Fiber Crude Protein (ADFCP): See Heat Damaged Protein.

Indigestible ADF Crude Protein (IADFCP): See Heat Damaged Protein.

Neutral Detergent Fiber Crude Protein (NDFCP): NDF Protein is the measured protein residue remaining in the NDF after analysis. This resultant is used in a calculation to determine the protein free NDF content of the feed. The NDF Protein should always be greater that or equal to the ADF Protein content.

Adjusted Crude Protein (Adjusted CP): The adjusted Crude Protein is calculated utilizing the Acid Detergent Fiber Crude Protein (ADFCP) value, but corrected for "normalized" ADF Protein results. Research suggests that a feedstuff is not truly heat damaged unless the protein contained in the Acid Detergent Fiber is both greater than 1% of the dry matter and greater than 10% of the total protein content of the feed. These "normalized" ADF Protein results are due to residual analysis error, intrinsic protein characteristics of the feed, and other reasons. Therefore, feeds which contain less than 1% ADF Protein or less than 10% of the crude protein in the ADF fraction will reflect an Adjusted CP value that will not differ from the Crude Protein value. This value should be utilized when feed programming on a crude protein basis for ruminants.

Corn Silage Adjusted CP =	IF((1.16 * CP) – (1.6 * ADF CP) < CP, (1.16 * CP) – (1.6 * ADF CP), 1 * CP))
Grass & Leg Adjusted CP =	IF((1.16 * CP) – (1.6 * ADF CP) < CP, (1.16 * CP) – (1.6 * ADF CP), 1 * CP))
Grass Adjusted CP =	IF((1.16 * CP) – (1.6 * ADF CP) < CP, (1.16 * CP) – (1.6 * ADF CP), 1 * CP))
Legume Adjusted CP =	IF((1.16 * CP) – (1.6 * ADF CP) < CP, (1.16 * CP) – (1.6 * ADF CP), 1 * CP))

Available Protein (AP): Available Protein is calculated by subtracting the ADF Protein (also expressed as Heat Damaged Protein, IADFCP, ADFCP, ADIN, ADFCP, AD-ICP, or as Unavailable Protein) from the Crude Protein. This value, however is not corrected for "normalized" ADF Protein resultants. Available Protein is used to calculate the Adjusted Crude Protein. It will only vary from crude protein if the heat damaged protein is high.

Corn Silage AP =	(CP – Heat Damaged Protein)
Grass & Leg AP =	(CP – Heat Damaged Protein)
Grass AP =	(CP – Heat Damaged Protein)
Legumes AP =	(CP – Heat Damaged Protein)

Soluble Protein (SP): Soluble protein is the actual protein percent of the dry matter which consists of the non-protein nitrogen (NPN) and rapidly degraded true protein content of the feed.

Corn Silage SP =	CP – Insoluble Protein
Grass & Leg SP =	CP – Insoluble Protein
Legume SP =	CP – Insoluble Protein
Grass SP =	CP – Insoluble Protein
Ear Corn SP =	CP – Insoluble Protein
Shelled Corn SP =	CP – Insoluble Protein

Protein Solubility: Protein solubility is the percentage of the crude protein which is soluble protein. Balancing for protein solubility is important to prevent excessive rumen blow-off of NPN as Blood Urea Nitrogen (BUN). Likewise, by balancing for minimum protein solubility you help assure against a deficiency of available nitrogen for microbial population growth. A level of 30% protein solubility (when formulating with NRC crude protein requirements) seems adequate for high producing dairy cows. It is important to remember that protein types and carbohydrate degradation should be considered when formulating rations. *Proceedings 1987 Winter Dairy Management School, Cornell University, Pg. 113-120.*

Corn Silage Protein Solubility =	(Soluble Protein / CP) * 100
Grass & Leg Protein Solubility =	(Soluble Protein / CP) * 100
Legume Protein Solubility =	(Soluble Protein / CP) * 100
Grass Protein Solubility =	(Soluble Protein / CP) * 100

Degraded Protein: The protein degradation test is still experimental and under refinement by university research. However, a calculated estimate can be made from protein solubility for forages. The equation for Protein Degradability % = Solubility % + (0.5*(100-Solubility%)). This equation works with relative accuracy for all forage types, but should not be used for grains, commodity feeds, or total mixed rations. It needs to be remembered that this value is influenced by length of cut, rate of passage, moisture content, forage to concentrate ratio of total diet, system of feeding, and pH of rumen, etc. It is recommended that the above reference proceeding be viewed for estimates of protein degradability of grains and commodity feed products. A calculated protein degradability of 60 – 62% is recommended in the diet of a high producing dairy cow.

Digestible Protein (est): An estimation of the amount of the crude protein that is available for digestion by the animal.

FIBER

Crude Fiber (CF): The amount of hard-to-digest carbohydrates. Most fiber is made up of cellulose and lignin. Crude fiber is the residue that remains after boiling a feed in a weak acid, and then in a weak alkali, in an attempt to imitate the process that occurs in the digestive tract. This procedure is based on the supposition that carbohydrates which are readily dissolved also will be readily digested by animals, and that those not soluble under such conditions are not readily digested. Unfortunately, the treatment dissolves much of the lignin, a non-digestible component. Hence, crude fiber is only an approximation of the indigestible material in feedstuffs. Nevertheless, it is a rough indicator of the energy value of feeds.

Corn Silage CF =	0.80 * ADF
Grass & Leg CF =	0.80 * ADF
Legume CF =	0.80 * ADF
Grass CF =	0.80 * ADF
Ear Corn CF =	0.80 * ADF
Shelled Corn CF =	0.80 * ADF

Acid Detergent Fiber (ADF): ADF is the most accurate determinant of forage digestible dry matter and digestible energy. It is the amount of fiber that is indigestible. The lower the ADF value, the more digestible it is expected to be. The ADF value is used in calculating energy content of forages. ADF differs from Neutral Detergent Fiber (NDF) in that NDF contains most of the feed hemicellulose and a limited amount of protein, not present in ADF.

ADF extraction involves boiling a 1.0-gram sample of air-dry material in a specially prepared acid detergent solution for 1 hour, then filtering. The insolubles, or residue, make up what is known as ADF and consist primarily of cellulose, lignin, heat-damaged proteins, and variable amounts of silica.

Cell Wall (CW): See Neutral Detergent Fiber (NDF).

Neutral Detergent Fiber (NDF): This is the insoluble fraction resulting from boiling a feed sample in a neutral detergent solution. It contains cellulose, hemicellulose, silica, some protein (heat damaged), and lignin. Cell wall (CW), or NDF, components are of low digestibility and entirely dependent on the microorganisms of the digestive tract for any digestion that they undergo; hence, they are essentially undigested by non-ruminants. NDF is closely related to feed intake. This fraction of a forage affects the volume it will occupy in the digestive tract, a principal factor limiting the amount of feed consumed. Animals fed such forages are often unable to consume enough feed to produce weight gains or milk economically. An animal will eat more feed with a low NDF value compared to feed with higher amounts of NDF. NDF will almost always be higher than ADF.

The soluble fraction – the cell contents – consists of sugars, starch, fructosans, pectin, protein, non-protein nitrogen, lipids, water, soluble minerals, and vitamins. This portion is highly digestible (about 98%) by both ruminants and non-ruminants.

NDF (Protein Free) (NDFPF): This value represents the protein free NDF content of the feed. It is calculated using both the ADF and NDF Protein resultants. Many high fiber protein feeds and heat damaged forages contain appreciable amounts of protein in the NDF fraction. Thus, using the raw NDF value without correcting for this residue protein overestimates the true NDF content of the feedstuff. Also, because the OSU Energy Equation requires ash free lignin determination, the lignin, ADF, and NDF are adjusted downward for the level of lignin insoluble ash (LIA) contained in the feed. This makes the fiber analysis results as accurate and unbiased as possible. The NDF (Protein Free) value is the recommended value of choice to be used in ration balancing in place of standard NDF results. A minimum of 28% of the ration dry matter as NDF (Protein Free) coming from forages (of adequate length to stimulate cudd chewing) should be included in the ration dry matter. *1989 NRC Nutrient Requirements of Dairy Cattle.*

NDFPF = NDF - NDFCP + IADFCP

Available NDF (Protein Free): The available NDF (Protein Free) value represents that NDF which is available for digestion in the ruminant. It is calculated using a complex equation utilizing the lignin content of the feedstuff and the intrinsic interactions it has on the digestibility of the protein free NDF. The higher the protein free Available NDF content of the feed, generally the more acetic acid will be produced from its fermentation in the rumen. However, this is highly dependent on the particle size of the feedstuff (as fed), as well as the other feedstuffs in the total ration. A minimum of 14% of the ration dry matter is recommended. However, ration levels of 16 to 18% would be more advantageous as long as minimum NSC (38%) and minimum forage NDF (Protein Free) are maintained in the ration of a high producing dairy cow.

Available NDFPF = .75*(NDFPF - L) * (1-((L / NDFPF)^.667))

Cellulose: Celulose is, by far, the most abundant polysaccharide in nature – composing close to 50% of the total organic carbon. It is a straight-chain polymer that is extremely resistant to acid and alkaline hydrolysis. Non-ruminant animals lack the necessary enzymes to cleave the linkages of glucose molecules in cellulose. Hence, they are poor users of fibrous plants. The microorganisms in the rumen of ruminants contain the enzyme celulase; hence, ruminants can effectively utilize feeds that are high in cellulose.

Lignin: Lignin is a major component of the cell wall of certain plant materials, such as wood, hulls, straws, and over-ripe hays. This fraction is essentially indigestible by all animals and is the substance that limits the availability of cellulose carbohydrates in the plant cell wall to rumen bacteria.

The acid detergent fiber (ADF) procedure is used as a preparatory step in determining the lignin of a forage sample. Hemicellulose is solubilized during this procedure, while the lignocellulose fraction of the feed remains insoluble. Cellulose is then separated from lignin by the addition of sulfuric acid. Only lignin and acid-insoluble ash remains upon completion of this step. This residue is then ashed, and the difference of the weights before and after ashing yields the amount of lignin present in the feed.

ENERGY

Calorie: The amount of energy as heat required to raise the temperature of 1 gram of water 1 degree Celsius.

Kilocalorie (kcal): The amount of energy as heat required to raise the temperature of 1 kilogram of water 1 degree Celsius, equivalent to 1,000 calories.

Megacalorie (Mcal): Equivalent to 1,000 kilocalories or 1,000,000 calories. Also, referred to as a *therm*, but the term megacalorie is preferred.

British Thermal Unit (Btu): The amount of energy as heat required to raise 1 pound of water 1 degree Fahrenheit, equivalent to 252 calories. This term is seldom used in animal nutrition.

Joule (J): A proposed international unit for expressing mechanical chemical, or electrical energy, as well as the concept of heat. In the future, energy requirements and feed values may be expressed by this unit. (4.184J = 1 calorie)

Hay Equivalent (HE): This is the energy equivalent of 1 ton of hay, which, on the average, contains 800 Mcal of net energy. With an Animal Unit Month (AUM) being equivalent to 320 Mcal of net energy, 2.5 AUM are required to furnish the same amount of energy as 1 ton of hay.

Total Digestible Nutrients (TDN): A measurement of the energy value of a feedstuff, TDN has been the standard method of expressing the energy value of feeds for many years. However, the usefulness of TDN is limited and presently is used mostly in formulating maintenance rations for beef cows. The following disadvantages are inherent in the TDN system: 1) Only digestive losses are considered – it does not take into account other important losses, such as those in urine, gases, and increased heat production; 2) There is a poor relationship between crude fiber and NFE digestibility in certain feeds; and 3) It overestimates roughages in relation to concentrates when animals are fed for high rates of production due to the higher heat loss per pound of TDN in high-fiber feeds.

Penn State Energy Equations

Corn Silage TDN =	31.4 + (53.1 * NEL)
Grass & Leg TDN =	4.898 + (89.796 * NEL)
Legume TDN =	31.4 + (53.1 * NEL)
Grass TDN =	31.4 + (53.1 * NEL)
Ear Corn TDN =	99.72 - (1.927 * ADF)
Shelled Corn TDN =	99.22 – (1.535 * ADF)

OSU Energy Equations

Forage TDN =	(CP * 38^(-0.012 * ADIN)) + (0.98 * (100-NDFCP - CP -Ash - EE)) + (0.94 * (EE - 1) * 2.8) + (0.75 * (NDFCP - L) * (1 - (L / NDFCP^0.667))) - 7
Concentrate TDN =	(CP * (1 - 0.004 * ADIN)) + (0.98 * (100- NDFCP - CP -Ash - EE)) + (0.94 * (EE - 1) * 2.8) + (0.75 * (NDFCP - L) * (1 - (L / NDFCP^0.667))) - 7

Total Digestible Nutrients for Horses (TDNHORSE):

Grass & Leg TDNHORSE =	(DE / 0.02)
Legume TDNHORSE =	(DE / 0.02)
Grass TDNHORSE =	(DE / 0.02)
Shelled Corn TDNHORSE =	(DE / 0.02)

Metabolizable Energy (ME): Metabolizable energy represents that portion of the gross energy that is not lost in the feces, urine, and gas (mainly methane) expressed as Kcal/lb. It does not take into account the energy lost as heat, commonly called heat increment. As a result, it overevaluates roughages compared with concentrates, as does TDN and DE. ME is used primarily to evaluate the energy concentration in swine and poultry rations. ME is considered to be the most accurate evaluation of the energy of feedstuffs for the scientific formulation of poultry feeds.

Corn Silage ME =	0.01642 * TDN
Grass & Leg ME =	0.01642 * TDN
Legume ME =	0.01642 * TDN
Grass ME =	0.01642 * TDN
Ear Corn ME =	0.01642 * TDN
Shelled Corn ME =	0.01642 * TDN

Gross Energy (GE): Gross energy represents the total combustible energy in a feedstuff. It does not differ greatly between feeds, except for those high in fat. For example, 1 pound of corncobs contains about the same amount of GE as 1 pound of shelled corn. Therefore, GE does little to describe the useful energy in feeds for finishing animals.

Net Energy (NE): Net energy represents the energy fraction in a feed that is left after the fecal, urinary, gas, and heat losses are deducted from the Gross Energy (GE). Because of its greater accuracy, net energy is being used increasingly in ration formulations, especially in computerized formulations for large operations. However, NE is difficult to determine.

Two systems of net energy evaluation are presently used: 1) net energy for maintenance (NEM) and net energy for gain (NEG), and 2) net energy for lactation (NEL).

Net Energy Lactation (NEL): A calculated value that nutritionists and dairy producers can use to evaluate or predict performance of rations fed to lactating ruminants.

Corn Silage NEL =	1.044 – (0.0124 * ADF)
Grass & Leg NEL =	1.044 – (0.0119 * ADF)
Legume NEL =	1.044 – (0.0119 * ADF)
Grass NEL =	1.085 – (0.0124 * ADF)
Ear Corn NEL =	1.036 – (0.0203 * ADF)
Shelled Corn NEL =	0.9050 – (0.0026 * ADF)

Net Energy Maintenance (NEM): Value calculated as a tool for nutritionists and producers to evaluate or predict performance of rations fed to non-lactating ruminants.

Corn Silage NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Grass & Leg NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Legume NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Grass NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Ear Corn NEM = -0.508 + (1.37 *ME1) – (0.3042 *ME2) + (0.051 *ME3)

Shell Corn NEM = -0.508 + (1.37 * ME1) – (0.3042 *ME2) + (0.051 *ME3)

Net Energy Gain (NEG): Value calculated as a tool for nutritionists and producers to evaluate or predict performance of rations fed to non-lactating ruminants.

Crn Silage NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Grass & Leg NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Legume NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Grass NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Ear Corn NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Shell Corn NEG = -0.7484 + (1.42 *ME1) – (0.3836 *ME2) + (0.0593 *ME3)

Digestible Energy (DE): Digestible Energy is that portion of the gross energy in a feed that is not excreted in the feces. It is roughly comparable to TDN. For most animals, DE is relatively easy to determine. With poultry, however, true digestibility is very difficult to measure because undigested residues and urinary wastes are excreted together.

Grass & Leg DE = (1.91 – (0.05 * ADF)) + (0.0151 * CP) + (0.00051 * ADF * ADF)

Legume DE = (1.91 – (0.05 * ADF)) + (0.0151 * CP) + (0.00051 * ADF * ADF)

Grass DE = (1.91 – (0.05 * ADF)) + (0.0151 * CP) + (0.00051 * ADF * ADF)

Coefficient of Digestibility: The percentage value of a food nutrient that is absorbed. For example, if a food contains 10 grams of nitrogen and it is found that 9.5 grams are absorbed, the digestibility is 95%.

Digestible Dry Matter (DDM): Is the estimated digestibility of the feed based on the ADF concentration.

FAT

Fat: Lipids (fat and fat-like substances), like carbohydrates, contain the 3 elements – carbon, hydrogen, and oxygen. Fats are soluble in such organic solvents as ether, chloroform, and benzene. As livestock feeds, fats function much like carbohydrates in that they serve as a source of heat and energy and for the formation of fat. Because of the larger proportion of carbon and hydrogen, however, fats liberate more heat than carbohydrates when digested, furnishing on oxidation approximately 2.25 times as much heat or energy per pound as do the carbohydrates. A smaller quantity of fat is required, therefore, to serve the same function.

Volatile Fatty Acids (VFA): Commonly used in reference to acetic, propionic, and butyric acids found especially in rumen contents and / or silage.

Crude Fat (EE): Material that is extracted from moisture-free feeds by ether. It consists largely of fats and oils with small amounts of waxes, resins, and coloring matter. In calculating the energy value of a feed, the fat is considered to have 2.25 times as much energy as either nitrogen-free extract or protein.

Nitrogen-Free Extract (NFE): The more readily digested carbohydrates (calculated rather than measured chemically) consisting principally of sugars, starches, pentoses, and non-nitrogenous organic acids. The percentage is determined by subtracting the sum of the percentages of moisture, crude protein, crude fat, crude fiber and ash from 100.

NFE = 100% - Moisture% - CP% - EE% - CF% - Ash%

Available Carbohydrate: This is the sum of the available NDF (Protein Free) and the available NSC. (The NSC is estimated to be 98% available.) The Available Carbohydrate value represents the maximum theoretical total carbohydrate available for digestion in the ruminant. Normal value ranges for high-producing cows would be 50 – 60% of the ration dry matter.

Non-Structural Carbohydrate (NSC): The NSC level of a feedstuff is an estimate of the starch and sugar content of the feed. It is calculated by difference after subtracting the crude protein, ash, fat, and protein free neutral detergent fiber from the feed dry matter. NSC, by calculation difference, also contains pectin, beta-glucans, and other substances. These substances have a similar digestibility to starch, but yield different fermentation products in the rumen. Practical applied nutrition suggests a NSC level of 38 – 42% of the ration dry matter of high producing dairy cows. *Journal of Dairy Science, Volume 74, Pg. 3583-3644.*

Shell Corn NEG = DM - CP - Ash - Fat - NDFPF - IADFCP

Non-Fiber Carbohydrates (NFC):

Corn Silage NFC = (92 – CP – NDF)

Grass & Leg NFC = IF((85 – CP – NDF) < 5, 5, IF(NDF < 43, 85 - CP – NDF, 87 – CP – NDF))

Legume NFC = IF((87 – CP – NDF) < 5, 5, IF(NDF < 43, 87 - CP – NDF, 89 – CP – NDF))

Grass NFC = IF((84 – CP – NDF) < 5, 5, IF(NDF < 45, 84 - CP – NDF, 86 – CP – NDF))

Ear Corn NFC = (94 – CP – NDF)

Shelled Corn NFC = (94 – CP – NDF)

Starch: Most glucose is stored in plants in the form of starch, of which there are two types: 1) amylose, a straight-chained structure of repeating glucose molecules; and 2) amylopectin, a highly branched compound. When either type of starch is hydrolyzed, dextrins are formed.

ASH

Ash: The mineral matter of a feed. The inorganic elements of animals and plants, determined by burning off the organic matter and weighing the residue.