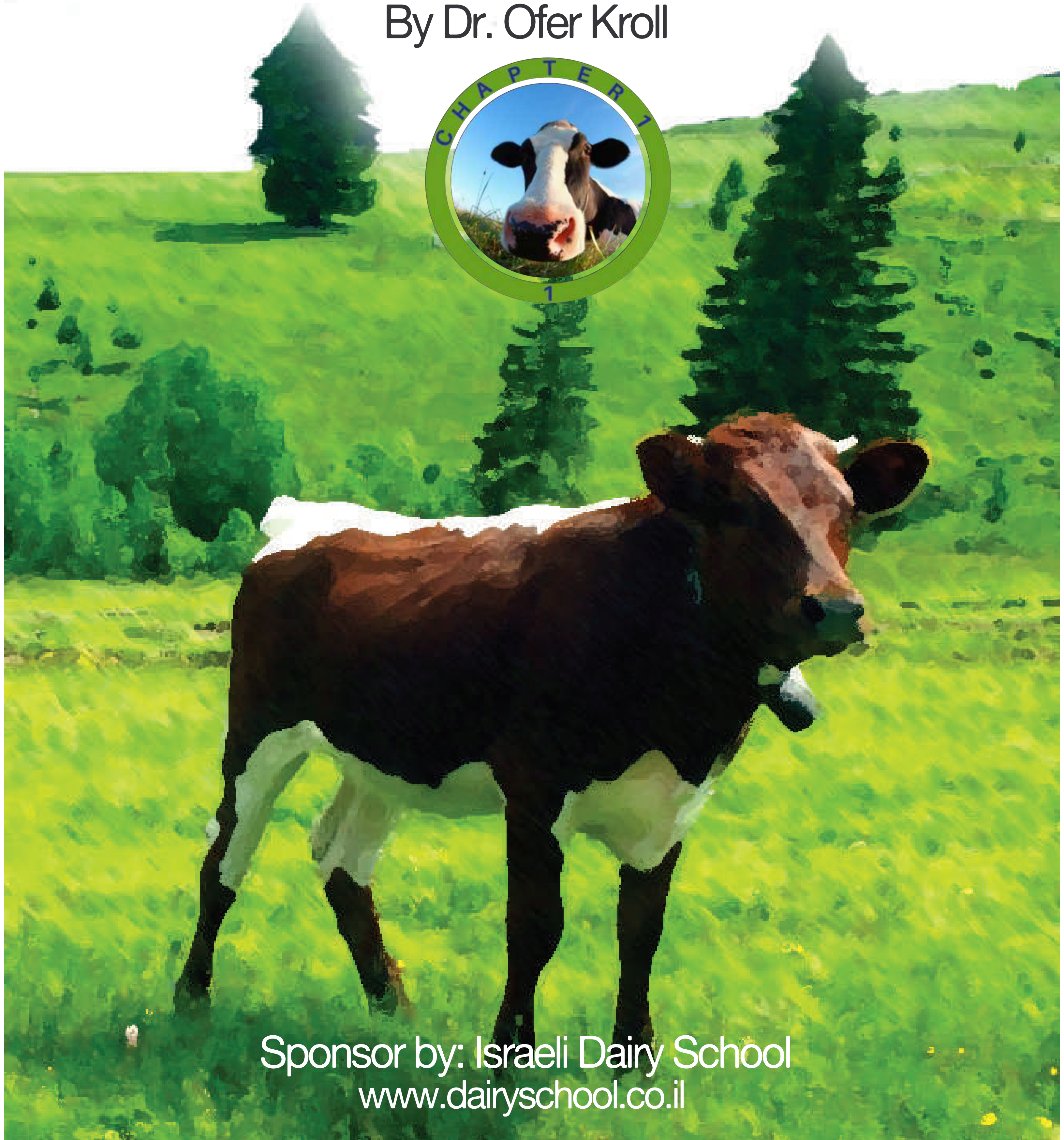
Dairy Herd Nutrition Management

By Dr. Ofer Kroll



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Edited by Charles H. Carter, Jr.

Israeli School For Dairy Farming Technology

Learn how the Israeli cows produce 12,000 Kg of milk a year

Introduction:
Dairy industry is a leading sector in Israel agriculture. Average milk production per cow has increased since the 1950s' from 4,000 kg annually to more than 12, 000 kg of milk in 2010. Fat and protein percentage increased dramatically. The dairy sector fully serves the country's total dairy needs.

Israeli advance dairy technology:
Israel's' dairy industry use most advanced technologies include computerized milking and feeding systems, cow-cooling systems (to reduce heat stress on cows in the hot and dry summer), as well as milk processing equipment.

The seminar:
You will learn how the achievements of Israel's' dairy sector have been made possible and how Israel succeeds in increasing of the production efficiency. You will visit two types of dairy farms:

- Family farm, with 40-50 milking cows;
- A kibbutz dairy cooperative, with 300-400 milking cows.

Main topics of the seminar program:

- An overview and recent developments of the Israeli dairy industry
- Modern management technologies in high producing dairy herds
- Nutrition management and feeding principles
- High yield production under hot climate and heat stress conditions
- Breeding and fertility management
- Economic aspects of management of dairy herd
- Milk quality and udder health
- Raising calves and heifers
- Health and prevention of diseases
- Visit the Israeli Insemination Centre and the Cattle Organization
- Visit a software manufacturer for dairy farm management
- Visit a Cow feed center and Feed mill

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Preface

This study deals with the principles of nutrition management is based on the experience and knowledge I have acquired as a dairy farmer and dairy farming consultant for almost fifty years. As a child, I had the good fortune to be able to ride the donkey, carrying two churns of milk to the milk collecting station. Today, computers controlling sophisticated electronics oversee the milking process. Everything has changed. The cow, which is the subject of this study, has been genetically improved, but basically, it is the same cow. There was a time when we produced milk to provide us with something to eat. Today, here in Israel, and in many other dairying countries, milk is not only a basic foodstuff; it is the raw material for a vast range of milk-based products. Then and now, the dairy industry keeps the farmer chained to his tasks 24 hours a day and that is the reason why we must continue searching for ways to provide the farmer and the cow with a more comfortable and efficient lifestyle.

This is not a dry scientific work filled with facts and references; it does not present all the facts. This is an attempt to present examples and practical solutions for the day to day operation of a dairy, spiced with the appropriate solutions of scientific thinking. I can only hope that I have succeeded and that is for the reader to judge.

Understand this: The various models published by committees in different countries around the world are from my point of view, something akin to travel guides for tourists. Whereas practical planning will make use of the model, it must always take into account the limitations imposed by time and space. Reality will present the user with something different, which very often; will not conform precisely to the model.

An expert in nutrition once reacted to a statement I made with: “Where is that written down?”

My response:

“It is my personal knowledge gained through experience. I do not act without reason; there will always be a scientific background accompanied by an additional dimension garnered through practical experience. If I was wrong, I learned the lesson taught thereby and reached the appropriate conclusions. I believe in this method as the best way forward. “

We have learned of the global trend towards fewer and larger herds to think differently. Regrettably, professional literature (and a limited number of studies) provides insufficient data about herd nutrition. Therefore, we must develop our own understanding of the issue (cow nutrition) that will most effect our lives as dairymen .

Editor’s Note: To correctly view graphs, resizing of e-reader text may be necessary.

Management, Not Nutrition is the Cornerstone to Dairy Herd Management

Nutrition experts often tend to think that success is attained simply by using the appropriate components to balance the diet and complying with all the recommendations issued by committees.

Economists focus on the price of food, the market conditions and the high costs incurred for the construction and maintenance of dairying infrastructures. Veterinarians, breeders and inseminators also have their own separate, specific perspectives. Each of these perspectives is limited in scope. A wider view is needed.

The question of nutrition, the quantities supplied and use may be compared to the fuel powering a vehicle. It is just fuel. A good journey in a quality and well maintained vehicle also requires a proper road and a good driver.

Twenty-Nine family dairy farms, essentially identical, received the same rations and used the same veterinary and insemination services. One year's entire production was measured, and the average yield was 9809kg of milk per farm. Each of the farms had forty (40) cows with results ranging from 8,890kg to 10,754 kg of milk. The range of nearly 2,000kg is solely due to management practices.

Good food and balanced rations are only building blocks for the system, but their use and management is just as important.

Introduction

Ruminants (cud chewing hooved animals) in general and dairy cows in particular are herbivores. Close examination of the structure of ruminants' digestive systems reveals that they could easily be defined as carnivores.

Plant based food serves as the dietary substrate for a broad range of microorganism populations in the stomach. Single cell organisms of various types (bacteria, protozoa, etc.) help break down the vegetation eaten and use it to build their own bodily tissues. At the same time, they secrete various compounds into the stomach juices, conduct a vigorous sex life and propagate.

Biologists know how to characterize the different natural proteins (which are the building blocks for all animal tissues) according to each protein's "biological value" to the consuming animal, which are used to measure the level of efficiency in which a food protein can replace the body's protein.

Type of Protein	Biological Value
Egg	98%
Milk	95%
Meat	85%
Vegetable (Leaf)	70%
Vegetable (Legume)	50%
Microorganism	**85%**

The biological value of microorganism protein is 85% , comparable to meat.

Microbial Activities and Nutrition in the Ruminant

Digestion breaks down the low value food protein into high value microbial protein. Growth in microorganism populations and secretions create volatile fatty acids (VFA) which are absorbed into the blood through the stomach wall and constitute the animals' principal source of energy.

Ruminant nutrition is a complex process, not yet fully understood. We know that it is important to maintain balanced nutrition, and that the balance should be maintained unchanged over the long term. Persistent nutrition is an important factor in dairy success.

The modern, high yielding cow is essentially no different than its predecessors that gave only small quantities of milk sufficient to feed their offspring and depended on the availability of food.

Man has learned to produce food products from the cow for human consumption through the combined use of genetics, management and feeding. However, the need to preserve the unique functioning of the ruminant digestive system to turn any organic material into milk and meat, remains the focus of all work on the dairy farm.

Natural grass as sole feed cannot support very high milk yield. To raise yields, it is possible to add to the ration additional products that survive the digestion process in the rumen and absorbed directly through the omasum (the real stomach), such products help raise the efficiency of microbial activities and/or the metabolic processes in the cow's body.

Microbial protein and breakdown products from the microorganism populations are the natural, optimal food for cattle; they provide all the cow's needs at an average level of production. When a maximum yield is desired, food additives and foods high in protein and amino acids (which do not break down in the rumen and move on intact to undergo enzymatic decomposition in the intestines) are needed. In all circumstances, the dairy farmer must ensure the cow's welfare and must balance the raw materials provided in the feeding trough as a function of optimal microorganism growth.

The Physical and External Factors Influencing Nutrition Efficiency

Extreme heat or cold affect cattle behavior and nutrition efficiency. Wind and humidity contribute to the heat load. Optimal dairy conditions are in the range of 20ºC - 25ºC, with humidity between 30% - 40%. Any rise in humidity levels, even at low temperatures, will have an adverse effect on behavior and milk production. In cold weather, where temperatures drop below freezing and with stronger winds, the cows need to produce heat increases which have a detrimental effect on the efficient use of food for milk production. Hot and dry weather, with humidity below 15%, will also reduce production. Shade and a pleasant breeze will help provide the cows with relatively comfortable conditions.

Nutrition management for a dairy herd is the an expression of all we have learned about food composition and quality, the needs of livestock, environmental conditions, climate, structures, animal maintenance and comfort. Beyond all those issues, nutrition management expresses what we have learned about the animals' ability to reach food, consume the quantities they require and how to produce the maximum amount of milk and meat while maintaining their condition, health and fertility. All that must be done with high efficiency and profitably, thereby providing the farmer with a livelihood.

The Digestive System

The digestive system of ruminants is different from single stomach animals (humans, pigs, etc.). Anatomically, the rear part of the esophagus of ruminants is wider and is what we term the fore-stomach. The fore-stomach is a large fermentation tanks about one third the size of the cow's entire body. Traditionally, the fore-stomach is divided into three parts: Rumen, reticulum and omasum. Most of the microbial activities take place in the first two stomachs, the rumen and the reticulum; the omasum squeezes the semi-digested food before moved it into the true stomach.

"Rumen" is the term referring to the three parts of the fore-stomach. The fourth in this series of stomachs is the true stomach, which constitutes a mere 7% of the entire stomach system and it functions in a manner similar to that of all other animals (except for some slight differences in birds).

Mothers teach their children to chew before swallowing. Ruminants do it the other way round. They swallow, fill the rumen and only then find somewhere safe and comfortable to rest, regurgitate their cud and chew. (It is likely that this is a defense mechanism against predators. Assuming that in nature, food could be found principally in exposed grassy areas, they could hide to digest the gathered food.)

Food consumed without chewing causes finely sliced food particles to sink to the bottom of the rumen, while longer fibers float and/or sink only slightly into the rumen juices. The longer pieces of food create a latticed layer which prevents the smaller particles from sinking quickly to the bottom of the rumen and passing into the duodenum and small intestine before they can be broken down by the microorganisms. Once further along into the system, they cannot be broken down and in their undigested form, they pass into the feces.

The cow copes with foods rich in long fibers by having it spend a longer time in the rumen. This gives the microorganism populations in the rumen enough time to break down larger quantities before it leaves the rumen and enters the other sections of the digestive system. The extended delay also contributes to the rise in digestibility and it improves the digestibility of the entire diet.

Food breakdown in the rumen creates methane and carbon dioxide, which although not digested, cannot be found in the feces. This must be taken into account when conducting digestion experiments.

Long fiber food stimulates the area where the esophagus meets the rumen and the reaction to that stimulation is similar to the process that occurs when a human vomits. The unprocessed food returns to the mouth, where it is chewed and that process is repeated again and again. The cud regurgitation process serves a number of very important purposes.

First, the unprocessed food returns to the mouth for chewing and slicing and during that process, it becomes accessible to the microorganisms. Next, the cud stimulates the animal to secrete saliva which contains salts that regulate the rumen's acidity. Gases produced during the fermentation process in the stomach are released during the regurgitation of the cud.

To summarize, the fermentation products in the stomach are:

1. Microorganism bodies, built up from the broken down food.

2. Acids and ammonia, defined as "waste", which can absorbed and exploited by the microorganisms and/or the ruminant.

3. Gases, such as methane and carbon dioxide.

4. Heat that is created during the fermentation process.

5. Remnants of undigested food, such as undigested fibers, which are excreted in the feces or protein compounds that have survived the microorganisms' activities. After reaching the intestine they can be digested by animals. This will be discussed in the section dealing with proteins.

The food components which may be used by the cow include microorganisms, the "fermentation wastes" and the residual protein. Heat and gases usually constitute a danger for ruminants and they must be disposed of by expelling them from the body. After expulsion from the animal, they become environmental hazards. Real digestion will be discussed later because it is a vital factor in the understanding of the digestive process and nutrition.

The vital importance of long fibers lies in the way that they prevent the accelerated flow of food through the digestive system, which in turn improves digestibility and helps save the lives of the cattle. Alternatively, too much long fiber food in the diet has a detrimental effect on food consumption as the rumen fills more and the flow of food slows down. Consequently, there is a drop in the quantity of food passing into the intestines for digestion and a drop in production. Proper balance is necessary for good nutrition. Balance means the correct ratio between the different sources of food in order to maintain the required level of food consumption, without harming digestibility. Food consumption rates is one of the limiting factors in ruminant nutrition

Digestibility and food consumption sometimes appear to be contradictory. The secret of good nutrition is to find the balance between the two. (A healthy, producing cow needs 550 - 600 minutes in every 24 hours to regurgitate cud). Any investigation of rumen and digestive system functioning must take into account the types of food, their chemical composition and physical structure.

The link between a type of food and its chemical composition is measured in terms of its breakdown rate and percentage in the rumen. Young vegetation is high in protein, low in lignin and breaks down faster. If it is the only source of roughage, large quantities must be provided. If not, the rumen will not function properly due to an insufficient excretion of saliva; rumen acidity will rise (pH will fall) and a highly acidic stomach will cause severe health problems for the cow. Problems include low levels of food consumption and damage to the epithelial tissues which line and protect the stomach wall. Other problems include a detrimental effect on hooves, limping and more.

High levels of starch (mainly starch from degradable and soluble food sources) which are low in fiber create the same problem.

Increasing the proportion of high energy foods in the ration to increase dairy production has the opposite result.

The balanced ration is the ration with the correct balance between forage with a fibrous structure and higher energy forage, which lacks the fibrous structure and is a combination of all the food carbohydrates that break down rapidly and spontaneously (Non-Structural Carbohydrates – NSC).

The higher the quality of the forage available to us (measured primarily in terms of non-digestible lignin), the lower the need for any addition of concentrates (grains) to the ration. The opposite is also true. When feeding straw and lignin rich foods in desert and tropical areas, if the ration is not balanced by feeding grains and other concentrates, we might be forced to compromise on lower cow yields and if that is the case, we will try to make maximum possible use of locally available raw materials.

Food Consumption

Dairy herd management, cow behavior and the cow's genetic makeup (small or large cow from a milking line or of mixed descent, etc.), the dairy farmer and all that together with the selected range of foods, must be expressed to the full in terms of optimal consumption of food. Food not eaten will not be digested and will not make the expected contribution. Many factors combine to determine the quantity of food eaten. Every researcher and committee has its own formula, but does one formula fit every herd?

Most of the advanced prediction formulae focus on cow's weight, milk yield and composition (more fat in the milk means more energy expelled from the body) and the lactation stage, all in an effort to cause a rise in consumption from the calving date up to 40 – 60 lactation days, followed by a steady fall in consumption towards the drying off period. In order to simplify the various models, some do not include factors such as fiber content (NDF), source or texture. Most researchers assume that cow performance in terms of milk yield, growth etc., are true expressions of the ration and its composition and therefore, they see no need for specific characterization of the constituents in the ration.

The physical structure of the ration (fiber length) influences consumption. Long fibers reduce food consumption and the opposite is also true for chopping, particularly excessively short chop length. When the chop length is too short, it can cause the opposite effect and lower consumption due to higher stomach acidity, which reduces the level of microbial activity and in some circumstances, can cause SARA (Sub-Acute Ruminal Acidosis). In more acute situations, it can lead to the death of the animal.

When food fat levels are higher than 5-7% of the total ration, digestibility is depressed and consequentially, consumption drops. Climate, food delivery regimes (delivery frequency, how often it is pushed up the food given and the times during the day that these activities are performed) contribute towards higher consumption as a function of the frequency at which they are performed. Feed push up and delivery timed close to the cows' exit from the milking parlor and their return to the feeders have particular importance. Food delivery during the cool hours in the summer also contributes to higher consumption.

For example: Two consumption prediction formulae:

The first formula is as recommended by the NRC 2001 committee. This formula places particular emphasis on consumption prediction based solely on cow data (body weight, fat corrected milk, and the time from calving):

$$DMI\ (kg/d) = (0.372 \times FCM + 0.0968 \times BW^{0.75}) \times 1\text{-}e^{(-0.192x\ (WOL+3.67)})$$

When:

DMI = Dry Matter Intake
FCM = Kilograms of 4% Fat Corrected Milk
WOL = Week of Lactation
BW = Body Weight in kilograms

The consumption prediction formula adopted by the NRC might be less accurate, when the ration includes high levels of buffers, particularly in those areas where most of the forage is green vegetation, which breaks down quickly in the rumen and therefore exits the rumen rapidly. The opposite will be true when various organic residues are included in the ration and in those tropical areas where most of the available foods are high in lignin.

The authors of the NRC formula determine that: "Less than 1% of food consumption variation is influenced by the cell wall – NDF". In their opinion, cow performance is an accurate reflection of ration properties. Unfortunately, I find that statement difficult to digest.

Alternatively and to emphasize another approach, which also takes food data into account, it is worthwhile presenting the proposal made by Mertens in 1984. In this prediction formula, the cow's energy requirement is divided by the concentration of energy in the food and it is displayed as follows:

$$I = NER/NE$$

When:

I is food consumption measured as dry matter
NER = Energy requirement
NE = Energy concentration in the food

The NER value is calculated as follows:

$$NER = .08(BW^{0.75}) + .74(FCM) - 4.92(LOSS) + 5.2(GAIN)$$

When:

BW = Body Weight
FCM = Kilograms of 4% Fat Corrected Milk
LOSS expresses the supply of energy from the body fat layer, which takes place as mentioned earlier, during the initial period after calving.
GAIN is the value that must be added for the weight gained during the rest of the lactation.

Calculation of NE is based on the estimated energy supplied by concentrates rich in unstructured carbohydrates, together with energy value of the fiber rich food in the ration, which takes into account the quantity, nature and composition of the NDF (see: Chapter 6).

Once again, this formula is simplistic because it does not take into account the cow's bodily condition and other management regime factors, such as the feed mix, feed delivery, the physical structure of the food and more. Both formulae will be able to serve as a general standard, but they will not be helpful to the dairy farm or to an individual cow.

For example:

One dairy reported: "milk yield has dropped and the cows are refusing to eat."
A brief examination revealed that the dry matter level in the silage was higher than planned. Dry silages have an adverse effect on consumption because it is difficult to chop properly during harvesting which makes it difficult to compact the silage in the pit. Consequently, the silage spoils easily.

Another instance described and solved:

"I was once invited to take part in a discussion on a drop in food consumption and milk yield; I found that the silage had been harvested at too high a moisture level and there was a large volume of run-off from the silage pit. Once more, the problem was solved by replacing some of the silage with dry forage without replacing the silage entirely; the silage was and remained inedible."
When silage is too wet, it reduces food consumption because of the high level of water in the cells and excess acidity.

During normal dairy farm work, all factors must be monitored on a daily basis. One of the problems, which must be re-examined, each time we review ration structure and food consumption, is the (sometimes) reciprocal relationship between digestibility and the rate of food decomposition in the rumen.

A balanced must be kept between encouraging consumption (providing the cow with the as many nutrients as possible) and feeding easily digestible foods (their high flow rate through the digestive system causing loss of digestible food into the feces). These considerations should be made when selecting the foods to use, the treatments to apply to the different foods, and the reciprocal relationships between the two factors.

Food Components

Carbohydrates

The fiber system makes it possible for a plant to rise out of the ground and stand upright. It is customary to examine the components of this system through the structure of cell walls and the adhesive that keeps them together. The basic structure of food fibers comprises a chain of carbon (C) atoms, with hydrogen (H) and oxygen (O) atoms alongside the carbon. The links within the chains and the strength of those links, determine the nature and properties of the substance.

Starch is a carbon fiber, which breaks down relatively easily in an aqueous environment or it can be broken down by enzymatic activity in the digestive system. In plants, starch serves as the energy reservoir stored in seeds to ensure germination. When the seed is supplied as a foodstuff, starch constitutes a good, rapidly available source of energy for the animal. Starch from different vegetative sources has slightly different properties. Wheat and barley starches break down rapidly in the rumen's aqueous environment and make major contributions as a source of energy for microbial activity. Maize (corn) and sorghum starches break down slower and therefore, they persist longer, which means that most of the absorption of those starches into the body is through the intestines where they serve as available energy sources. Fine chopping of maize and sorghum grains into very small pieces increases the rate at which they are absorbed through the intestine.

Cellulose, which has a basic structure similar to that of starch $(C_6H_{12}O_6)_n$ and hemicellulose (a different chain, which contains a combination of 5 and 6 atoms of carbon) are more stable and their breakdown is dependent upon the populations of microorganisms in the rumen.

Lignin is another component in fiber, present in much lower quantities, but has a powerful effect on both the plant and digestibility. Lignin is not a carbohydrate in the commonly accepted sense. Lignin is a complex structure, or a chain of rings, some of which contain nitrogen. Lignin has a much more stable structure than cellulose and hemicellulose; lignin is not digested. (During the discussion of proteins, we will explain that anything which is not lignin, but is close to or and/or bound to lignin such as the nitrogen in the rings, also has degraded digestibility). Lignin levels in plants rise with the plants' age; accordingly, young plants have much higher digestibility than mature plants, notwithstanding the fact that laboratory tests often characterize these fiber components as carbohydrates; no difference is apparent between the different plants. Research into lignin is somewhat problematic because we don't always know if it appears in specific locations in the plant or is dispersed throughout the plant. (If lignin is dispersed within the plant tissues, the plant links relatively greater percentages of digestible plant parts to the lignin, when compared with that found in plants with lignin as a continuous physical presence).

Other food components, such as fat and protein are found within the cell itself and shall be discussed separately. However, the material between the cells contains varying levels of pectin, which is a chain of rings that breaks down easily and that is its major contribution to the food's energetic value. We must point out that whereas pectin is present in only tiny quantities in green leaves, it is present in relatively large quantities in fruits and that is why food industry wastes such as citrus peels are of such high value to the ruminant industry.

Characterization of the cell wall allows us to differentiate between the different plants according to their physiological age and also helps us differentiate between fiber rich food and concentrated food – grains have higher starch content than cell walls; in leaves and plant stems, cell walls are present in significantly greater quantities.

Wood stems and grains have similar carbohydrate content with the exception of a small difference in mineral concentrations – ash. The differences in the nature of the carbohydrates in the different plant parts means that the grain is a high energy, concentrated food, while the stem is high fiber roughage, which (in the rumen) serves to support digestibility and slow breakdown by the microorganism populations.

To characterize the fibers in the laboratory, we must differentiate between the cell wall (NDF), which is an expression of the remnants from the test after steeping the plant in neutral solvents (alkaline and/or detergents with a pH of more than 6) and it includes all the plant fibers, which as stated above, are: Cellulose, hemicellulose and lignin. There are those who also include pectin in this list, despite the fact that it breaks down easily in the rumen in a manner more similar to starch. However, it does break down during the treatment with the neutral solvents. The remaining NDF is treated with low concentration, weak sulfuric acid (1.25%), which separates the hemicellulose from the cell walls and provides the value: Acid Detergent Fiber – ADF. A number of laboratory techniques can be used to separate between ADF and lignin and naturally, they provide different results. Customarily, nutritionists examine the lignin content by treating the remnants with high concentration, strong acid (72%), which provides the value: Acid Detergent Lignin – ADL. Botanists examining the plants not from the nutritional aspects employ a different range of techniques and it would seem that they are more accurate. The most stringent transfer the ADL remnants to an oven at a temperature of 550ºC to burn the remnant down to ash (the range of minerals).

Lignin digestibility is very low or non-existent. Simply, check the lignin content to know the nutritional value of the plant.

The problem is more complex because the lignin is not a single entity. When examining the nutritional aspect, remember that not all the lignin is characterized as part of the ADF and some of the lignin breaks down in the presence of the alkali and is not included in the final results.

Given that some of the plant lignin breaks down in the alkali and some more lignin breaks down in the acid, it is difficult to predict the link between ADL content and cell wall digestibility – NDF.

Despite the difficulties encountered during laboratory characterization, we can use ADL to predict cell wall digestibility when comparing plants harvested at different stage of maturity, knowing that the younger the plant, the greater the digestibility. It is difficult to predict cell wall digestibility using ADL when comparing plants which are botanically different.

Apart from the ADL technique, there are other techniques that can be used to characterize lignin. The alternative technique most often used is the KL test, which instead of trying to separate between lignin and cellulose using strong acid as in the ADL test, uses potassium permanganate ($KMnO_4$) to oxidize the ADF. When using this test, the results are higher than those received from the ADL test and that can be reasonably attributed to the nature of the test, which successfully includes not only the non-digested fibers in the cell wall; it also comprises some of the lignin that breaks down in an alkaline environment, which is the non-digested component found inside the cell. Chemically, the difference between ADL and KL is that part of the lignin comprised entirely from less stable materials (phenolic acids). In fact, the characterization of this lignin component can teach us more about plant dry matter digestibility when comparing different plants, or the same plants from different plots of the same age. On the other hand, when examining a specific plant at different growth stages and from different growing areas, it would seem that the ADL test suffices.

Starch and sugars constitute the cell-content carbohydrates and in the overall characterization, they are usually defined as NSC (Non-Structural Components) with high solubility in the rumen. On the other hand, in terms of the difference between the two lignin characterization methods, we learn that not all cell content components are soluble, digestible and high in available energy – ADDL (Acid Detergent Dispersible Lignin).

Predicting the digestibility of the cell wall using the ADDL technique is very significant in the case of cereals and principally, in the case of cereals growing in and/or sourced from tropical areas. In contrast, when assessing legumes, the simpler and easier, ADL method is usually up to the task. The next stage in the decoding of the secret of forage will be slightly more accurate and will include as a matter of course, both the ADL and the KL tests.

Despite the limitations of the test, it would seem that in on the farm, regular measurement of ADL levels could significantly improve the ability to provide the correct combination of the forages at our disposal. The negative effects of lignin on digestibility are not linear; lignin has an aggregate effect. Therefore, a plant with a 4% ADL level is far less digestible than the same plant with a 2% ADL content (1% out of 2% lignin has less effect on the drop in digestibility than 1% out of 4%). Thus, in the case of lignin rich foods in which the digestibility damage has already been done, it doesn't matter if the lignin is 30% or 40% of the plant or even higher. The range of interest to us and to which we must pay close attention, is between 2% and a maximum of 8% (it is standard practice to assess loss of digestibility at 2.4% for every 1% lignin).

Cell wall digestibility (NDF) constitutes a core measurement in the prediction of ration efficiency for ruminants on milk yield. Recent years, with the growth in the use of low lignin varieties of maize and sorghum (BMB – Brown Midrib); have seen the publication of large numbers of studies on the very considerable contribution that these varieties make to the dairy farm. Careful selection of the harvesting date for the varieties in regular use will achieve similar results.

The fiber tests described here constitute the basis for most of the research into nutrition. Unfortunately, these tests do not provide enough detail about the various components of the plant. It would seem that for the purposes of characterization of food at the farm level, the standard NDF method described suffices for this purpose.

For day to day life on the farm, it is not enough to know the chemical composition of the plant. Its physical structure and its ratio in the ration are of very considerable importance. Researchers in Pennsylvania developed a sieving system, which can be used to characterize food fibers according to length. When a fiber is shorter than 1.18mm, it will not be defined as effective, because it has no influence on rumen activity and the regurgitation of cud. It is important to emphasize that the effectiveness value found is also a relative figure and it is impossible to compare between plant parts with an average length of 2cm and other parts with an average length of 4cm, 6cm and more.

The percentage of effective fibers in the food influences the consideration, which must be given to the overall cell wall data for that food and the degree to which it can influence digestion processes. Definition of food in “roughage units” can help us understand this subject (the calculation: Fiber longer than 1.18mm x %NDF).

For example: Whole crop cereal forage with an NDF of 65% and 98% long fibers, will have 63.7% effective fibers. Using the same calculation, maize silage with an NDF of 50% contains just 41.5% effective fiber. Crushed soya husks, notwithstanding the fact that they have an NDF of 67%, had just 0.03% particles with a length of more 1.18mm and therefore, the level of effective fiber in this silage was a mere 2%. This issue is also important in grains. After physical treatment and due to the nature of the grains, it was found that rolled barley contributes more effective fiber than finely ground maize grain, etc.

Despite the wish to determine an objective yardstick as is true for effective fiber, it was found that two foods with identical fiber length, but a different cell wall composition will not behave in the same way in the rumen, apparently because each food has a different breakdown rate in accordance with its composition and properties.

Effective NDF values can also be used as a measurement of rumen filling (Fill Value) and therefore, it is standard procedure to apply this measurement to the different cow rations and when the NDF for the ration rises above 30%, the rumen fill value also rises. Consequently, both the flow of digested products through the digestive system and food consumption drop.

Another important consideration, which must be taken into account, is the region where the plant is grown. On a visit to Florida, I saw beautiful alfalfa in the feed bunker. I expressed wonder and the fact that I had not expected to see such high quality feed in such a warm, moist area. After asking where the alfalfa had come from, I was told that it came from Utah, a state which benefits from a dryer, colder climate than Florida. Utah is further north on the globe and therefore, plants are less woody and they are easier to digest. It is also true that even in small countries like Israel; there are no similarities between northern and southern plants. The same is true when comparing winter grown to summer grown plants and when comparing plants, which are botanically identical, but have been grown in hilly or valley areas, or in the Syrian – African Rift valley below sea level.

Testing was conducted to reveal the chemical composition of several forage varieties of wheat, grown for two different harvesting dates in two adjacent geographical regions – one was a mountain plain at a height of some 300 – 400 meters above sea level and the other was in the Jordan Valley, some 200 meters below sea level. The ADL/ADF ratio, which is a good enough expression of fiber digestibility for the plants harvested at the flowering stage, was 18.05 on the mountain plain and 20.40 for the valley crop. The plants harvested at the milky grain stage had ratios of 21.47 and 23.37 respectively. Later maturing plants at the flowering stage gave ratios of 16.16 on the mountain plain and 20.76 in the valley. At the milky grain stage, the late maturing plants gave ratios of 16.92 and 27.84 respectively.

The conclusion: It is essential to match the variety to the growing area and preferably, early maturing varieties will be grown in the warm areas and late maturing varieties in the higher, colder regions further to the north.

Another study in Israel, (Ben Sedalia) which examined fiber digestibility for wheat silage made using early and late maturing varieties, found a difference of 6.1% digestibility between the flowering stage and the grain filling stage in the early maturing varieties, but just 2.2% in late maturing varieties. Late maturing varieties are less woody than early maturing varieties.

Protein is the subject of the following chapter.

Protein

Proteins, like carbohydrates, are carbon chains, but protein chains also have links to nitrogen atoms. A simple protein chain is comprised of short units combined with a small number of carbon based structures called amino acids. When the chain is more complex and has a slightly higher number of carbon structures, it is called a peptide. In practical terms, a protein is a chain of different amino acids, connected together in a fixed, specific sequence. The relationships between the various acids and their position in the chain determine the protein's size and properties.

Protein structure and the nature of the links within the chain or between different chains have an influence on protein stability and microorganisms' abilities to break them down for their own needs. Ruminant nutrition differentiates between rapidly broken down, soluble proteins and proteins which can be broken down only through the intercession of an external factor, such as microorganisms.

The definition of protein is divided into two groups of proteins, which we shall call the degradable and soluble groups. Part of the protein survives the rumen and is whole when it reaches the intestines, where it is digested by the animal's enzymes. Some of the protein that survives the rumen can be degradable protein, which was not digested due to the rapid flow through the system. Protein reaching the intestine undergoes digestion by enzymes in a process similar to single stomach animals. Protein is not digested in its entirety in the intestine for a number of reasons:

1. Due to the speed at which food is washed out of the rumen and passes through the digestive system, the degradable protein can continue on and flow out in the feces.
2. Protein bound to lignin (ADIN) cannot be utilized.

To complete this process, it is important to mention the wear and tear caused by the passage of food through the digestive system. Body protein worn away from the walls of the digestive system passageways, together with the enzymes secreted from the body, constitute between 3% and 5% of the nitrogen in the feces (metabolic fecal nitrogen) and the rougher the ration (straw) the higher the quantity of nitrogen excreted. On the farm, it is customary to disregard the value of foods containing up to 3% protein as a source of protein. They are sometimes listed in the ration planning charts as having zeroed or negative protein value. The protein that is present is inefficient, residual protein. To complete the picture of nitrogen balance in the body, we must mention the excretion of nitrogen in the urine, which is the byproduct of metabolic processes in the body and not only the excess nitrogen excreted as urea. The quantity of metabolic waste (endogenic nitrogen) is not large, but must be taken into account when conducting digestion experiments.

Notwithstanding the fact that food protein is essentially a carbon chain, it is an inefficient source of energy. Protein's vital role in food is to build body tissues and help produce milk; it is not worthwhile to provide protein in food as a source of energy. Protein is an inefficient source of energy because despite the fact that it is an energetic material, it breaks down into an intermediate material – non-protein nitrogen, which contains some of the energy intrinsic to the protein (equivalent to some 1.25 Kilocalories for each gram of digested protein) and most of the non-protein nitrogen is in the form of urea. Although rich in nitrogen like protein, the urea molecule has no residual oxygen, which could to a degree, serve as a food substrate for the rumen populations to make microbial protein. The residue comprises short chain molecules, which are absorbed to a not inconsiderable degree through the rumen walls into the bloodstream and they are not utilized either as a source of energy or as a source of nitrogen in the making of microorganism protein. The residue is excreted as urea in the urine and therefore, notwithstanding the fact that it is a digestible material, in practice its digestibility is a fiction or artificial.

Regrettably, various committees for the determination of nutritional norms tend to ignore this finding and they determine a direct link between digestibility and energy, without deducting artificial digestibility, even though they do take this finding into account when discussing the nitrogen balance in the body.

In real life, the food ration is balanced using overall protein units (N x 6.25), which is the mathematical expression used to translate the quantity of nitrogen found during laboratory testing into a quantitative measure of protein, because in most vegetative raw materials, nitrogen constitutes 16% of the total material (100 ÷ 16 = 6.5). Current knowledge allows us to differentiate between the three types of protein mentioned above: Rapidly broken down soluble protein, degradable protein and survives protein. The most practical recommendation for ration preparation is to provide all three types in a 1:1:1 ratio. Rumen populations (assuming a ration balanced for fiber and available energy) have the ability to exploit the two sources of protein that break down in the rumen for microbial protein. Unfortunately, this capability has limitations. One third of the protein supplied in the ration, which is the proportion that survives the rumen, is exploited by the animal using the enzymatic system and it does not exploit the non-utilizable protein (ADIN).

For any given nutritional composition in a ration, advanced models can be used to calculate the total amount of protein absorbed through the intestine, which comprises utilizable residual protein and microbial protein. This combination, together with various models used to predict the composition and quantities of different amino acids absorbed into the body, expresses the real value of the protein in the food, which is then defined as Metabolic Protein – MP.

The dairy farmer should plan the supply of protein in the ration by calculating the Metabolic Protein value of the food. Unfortunately, in many circumstances it can only be used for the theoretical examination of the ration, using different models.

"A veterinarian very interested in nutrition models once called me and asked: 'If a ration for calves needed no more than 12% overall protein to provide all the required Metabolic Protein, why are we wasting protein and providing 13% - 14% crude protein in the calf ration?' We met and together we examined an advanced model. It showed us very clearly that the link between overall protein and metabolic protein is a function of ration composition. In the case that we checked, by making only a few changes in the range of raw materials in the ration, we successfully predicted identical production of metabolic protein (MP) in rations containing from 12% to 19.5% crude protein."

Any discussion of protein quality and its contribution to ruminants cannot be limited solely to chemical characterization. It is always important to take a close look at the conditions, which contribute towards the production of microbial protein. Available energy is a vital factor in the process. Different plants, such as legume forage, which has a high proportion of leaves, will encourage more vigorous production of microbial protein than various cakes, which are the main protein source in standard rations. For example: Soya protein breaks down in the rumen slower than alfalfa protein. On the surface, that would imply that it is a better protein. In fact, it is the alfalfa protein, which contributes more to the production of microbial protein than the soya protein. Therefore, the soya protein is exploited less efficiently, and relative large percentages of soya protein pass into the bloodstream and the body as ammonia. During digestion experiments, it is included as digested material, but its artificial digestibility makes no contribution to the supply of either energy or protein to the animal. Such proteins even consume energy to expedite its excretion in the urine or in the milk. In other words, we can reasonably say that soya protein (and similar foods with greater effect, such as gluten feed and others) makes a relatively large contribution to the artificial digestibility compartment.

The nitrogen cycle within the body does not result in the excretion of all the surplus nitrogen in the urine. Some nitrogen returns through the saliva into the rumen. Nitrogen in the saliva joins the overall nitrogen in the rumen, most of which comes from the food. Some of the nitrogen was in the food when it was consumed at the feeding trough (even alfalfa protein contains a certain amount of ammonia). The remaining nitrogen, which is also the larger quantity, is real food nitrogen, which was broken down in the rumen because rumen microorganisms had neither the energy nor sufficient time (due to fast breakdown rate and speed of digesta flow through the digestive system) to use the ammonia to make microbial protein.

Many of us now have a practical tool to estimate artificial digestibility –measuring the quantity of urea in the milk. The starting point for this process is as explained above: The ammonia and nitrogen in the rumen not used to create microbial protein. As it continues, they enter body tissues, where they are transformed into urea. As the urea concentration in the blood rises, it moves on and it is absorbed into the milk.

What have we learned from all this?

A high concentration of urea in the milk is a characteristic indication of an imbalanced ration and principally, its lack of available energy for the efficient exploitation of the food protein, which broke down in the rumen.

A high concentration of urea in the milk results from a too high concentration of protein in the ration and at that concentration, the energy provided is insufficient to do all that required. (In fact, this is a waste of protein, together with an increase in heat load on the cow, which must invest energy in the effort to remove surplus protein.)

A low concentration of urea in the milk is an excellent indication of a lack of food, due to a drop in consumption or merely a lack of protein.

During the hot summer days, when insufficient heat stress relief is provided or the cooling method is inefficient, there is a rise in respiration rate, food consumption drops and with it the supply of energy. Consequentially, urea levels rise in the bloodstream and the milk. This is perhaps a circumstance, which can be explained by a drop in food consumption that is even higher than the drop in milk production and the observation of a strange phenomenon – an improvement in the efficient exploitation of food to manufacture milk, at the expense of the cow's condition and fertility.

The optimal range for urea in the milk is 7mg – 8mg / deciliter to 16mg – 17mg / deciliter. Whereas we have insufficient information to analyze intermediate situations, this is an indicator, which can be used to learn a great deal about nutritional efficiency.

Urea in the milk is another in the range of tools at our disposal. If we make the wise choice and examine all of them together, we will be able to develop control methods and reach conclusions in time. If we have a great deal of patience, our work will bear fruit.

The enormous importance of microbial protein*, lies in the fact that it is a natural source of protein in the ruminant ration, both in terms of its composition and its complete match with the composition of animal body tissues and milk. Solely for the purposes of illustration, we shall examine the levels of two vital amino acids – lysine and methionine and their presence in microbial protein and milk.

<u>Table 1: The Percentage of Essential Amino Acids in Milk and Microorganisms</u>

Source / Amino Acid	**Lysine**	**Methionine**
Milk	8.2	2.6
Microorganisms*	9.6	2.3

* A small proportion of the microbial protein – the DNA protein, is not digested

No similar ratio between vital amino acids and food and milk exists in any type of forage. Therefore, it would seem for the nutritionist to always work hard to create the conditions in which there will be an increase in the production of microbial protein. A management regime that strives to reach high milk yields does not provide enough microbial protein in the rumen to provide all the host's needs. Under such conditions and to make up the lack, the widest possible range of proteins, which can survive the rumen, must be added to the ration. Researchers, different models and commercial companies are attempting to deal with the limited supply of vital amino acids, by protecting those amino acids before they are delivered as a food additive.

As illustrated in the table given above, the recommendation is to reach concentrations of 6.8% Lysine and 2.2% Methionine in the total of <u>metabolic</u> protein. Notwithstanding the natural limitations, I believe that the correct and most efficient way to reach that objective is to learn how to nurture and pamper the microorganisms in the rumen. (Evadable energy and large verity of ingredient given in the diet may overcome such problem)

The discussion of protein must include byproducts. For example, gluten feed is a byproduct during the extraction of starch from maize seeds. Gluten contains a relatively high proportion of crude protein, some 40% of which is soluble protein, but even so, it makes relatively little contribution to the manufacture of microbial protein. In contrast, another, often slightly more expensive material, such as canola cake, contains relatively high levels of survive protein. Given that we have no efficient tools to measure the degradation and solubility of the various proteins, we must use the published data from previous experiments in laboratories around the world. Those experiments provide a picture, which is usually correct for the individual experiment and the conditions under which it was conducted. In the case of food industry wastes, the data will be accurate for the specific conditions at the manufacturing plant. On the commercial farm and in the differing conditions of ration composition, climate, etc, there might be different results and therefore, the wise choice is to learn and understand the principle and to be wary of precise numbers.

The following table provides examples of protein content in a number of different foodstuffs, in accordance with their levels of degradability and solubility. Close perusal of the table reveals that they are divided into two levels. One is degradable, escape protein. The other is the bound, soluble protein expressed as a percentage of the overall protein. Barley grain provides a good example: Crude protein: 11.3%, which is divided up into 79% degradable protein and 21% escape protein. 35% soluble protein is 44% of the degradable protein. 2% of the bound protein is 9.5% of the escape protein.

Table 2: Levels and Nature of Degradable and Escape Protein in a Number of Foods

Food	% Protein	Soluble	Degradable	Escape	Bound
Barley	11.3	35	79	21	2.0
Maize	10.0	12	35	65	6.2
Wheat	14.6	23	80	20	1.0
Citrus peels	6.7	12	30	70	6.2
Gluten feed	21.7	48	70	30	2.6
Cotton seed	24.0	33	55	45	10.0
Canola cake	40.0	28	77	23	2.5
Soya cake	49.0	20	72	28	2.0
Urea	281.0	100	100	-	-
Roasted soya seeds	41.0	16	51	49	4.0
Alfalfa forage	20.0	20	72	28	5.0
Wheat forage (green)	12.0	20	63	37	5.0
Wheat silage	12.0	40	70	30	10.0
Maize silage	8.5	50	73	27	4.0
Molasses	4.1	100	100	-	-
Gluten Meal	68.9	4.0	45	55	5.0
Whey	17.7	80	90	10	-
DDG	27.8	15	38	62	15.0
Wheat Bran	18.0	40	80	20	1.0

Examination of the table illustrates the differences between the foods in terms of their degradability and solubility in the rumen. To this we must add the small amount of knowledge about the different foods' varying contribution to amino acids and vitally, the importance of the degradable and soluble protein in the production of microbial protein which is the basis for the statement made above – There are no good or bad proteins; therefore, proper, cautious balance is the recipe that is best and most worthwhile adopting.

A higher level microbial protein in the rumen will more than anything else, ensure production efficiency and livestock health. Food protein is an important but not the sole factor in achieving that aim. The entire nutrition base for food consumption, energy balance for microbial activities, the quality and quantity of roughage and anything else that will support proper rumen functioning must also be taken into account.

Wise nutritionists know how to relate to all those factors and will not rely on the simple measurement of overall protein.

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