2. Overall model description

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The NorFor system is a semi-mechanistic, static and science-based model, which predicts nutrient supply and requirements for maintenance, milk production, growth and pregnancy in cattle. The model can be divided into five parts: (1) an input section describing characteristics of the animal and feeds available; (2) a module simulating processes in the digestive tract and the intermediary metabolism, termed the feed ration calculator (FRC); (3) a module predicting feed intake; (4) a module predicting the physical structure of the diet; and (5) an output section describing nutrient supply, nutrient balances and production responses (Figure 2.1).

The input variables for the model are animal and feed characteristics. For dairy cows, the main input variables are body weight (BW), stage of lactation, pregnancy day and planned or potential daily milk production. For growing animals (bulls, steers and heifers) input variables are BW and average daily weight gain (ADG). The feed dry matter (DM) is separated into ash, crude protein (CP), crude fat (CFat), neutral detergent fibre (NDF), starch (ST), sugar (SU), fermentations products (FPF) such as organic acids and alcohols, and a residual fraction (RestCHO). The CP is divided into soluble (sCP), potentially degradable (pdCP), indigestible (iCP) and ammonia (NH_3N). The NDF is divided into a total indigestible (iNDF) and a potentially degradable (pdNDF) fraction. The ST is divided into soluble (sST), potentially degradable (pdST) and indigestible (iST) fractions. The FPF are separated into lactic acid (LAF), volatile fatty acids (VFA) and alcohols. Fractional degradation rates (kd) of the soluble and potentially degradable feed fractions are also required for the model.

The FRC consists of four sections: (1) the rumen, (2) the small intestine, (3) the large intestine and (4) metabolism (Figure 2.2). Feed organic matter (OM) entering the rumen is either fermented and used for microbial production, or it escapes from the rumen for further digestion in the lower digestive tract. Ruminal degradation of CP, ST and NDF in concentrate feeds are assumed to follow first-order single-compartment kinetics, while degradation of NDF in roughage is modelled as a

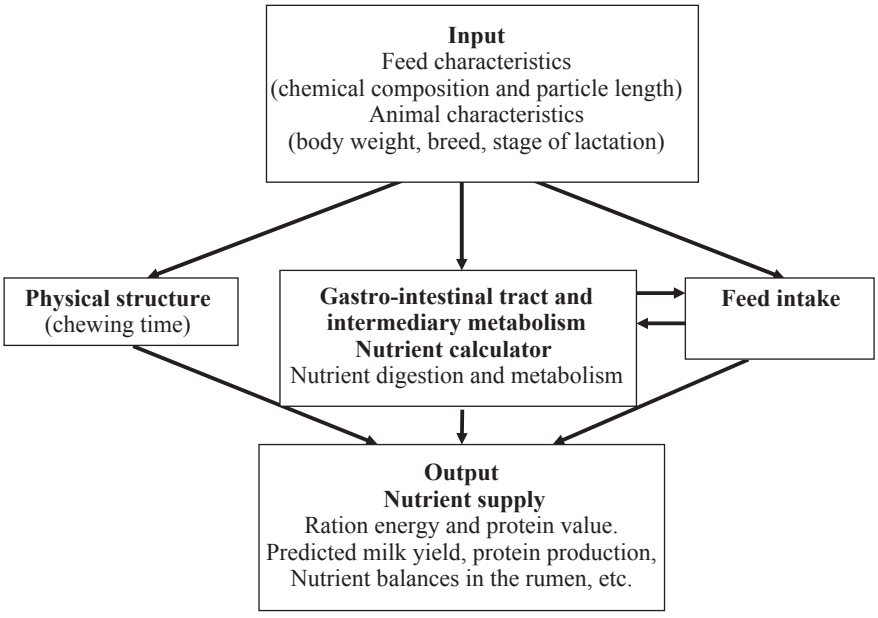

Figure 2.1. Overview of the NorFor model.

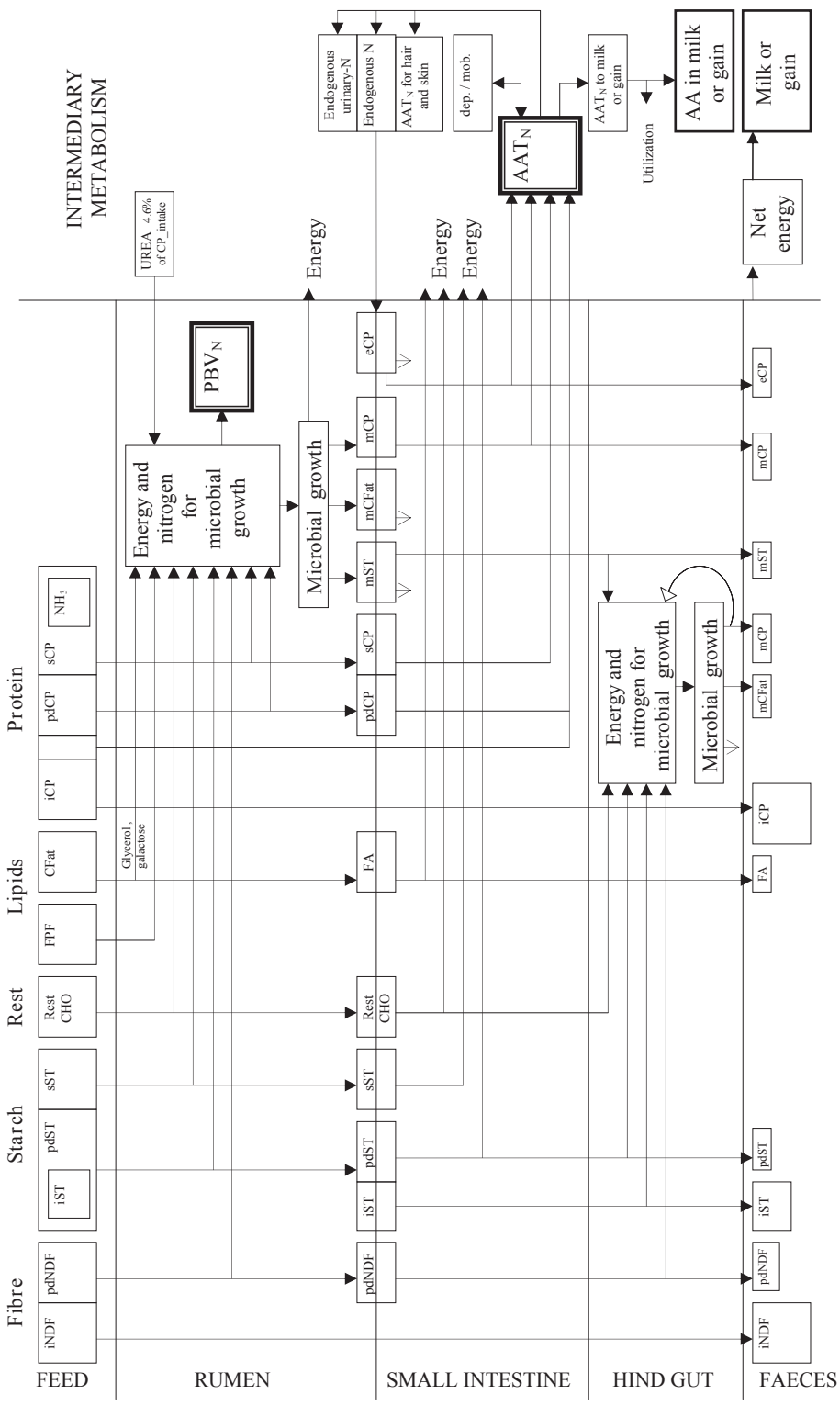

Figure 2.2. Flow diagram of the gastrointestinal tract and intermediary compartments of the NorFor feed evaluation system. For all abbreviations check the abbreviation list.

two-compartment system, with a non-escapable and an escapable pool. The nutrients available for microbial growth come from ruminally degraded NDF, ST, RestCHO, glycerol, CP and LAF. The efficiency of microbial synthesis depends on the level of feed intake and diet composition. The input to the small intestine consists of OM from microbes, unfermented feed fractions escaping from the rumen and endogenous secretions. These components are partly digested in the small intestine and are either metabolised or enter the large intestine. The OM passing into the large intestine is subjected to microbial fermentation, and the digested OM not used for microbial synthesis is absorbed and metabolised. Faecal excretion consists of OM from microbes synthesised in the large intestine, feed that has escaped previous digestion and undigested rumen microbial material. The intermediary metabolism section yields ME calculated from total tract digestible OM. Net energies for maintenance, lactation, growth and pregnancy are predicted from the ME. Different coefficients are used to calculate NE for maintenance, lactation, and growth. Net energy for lactation is used for dairy cows, while NEG is used as the energy measurement for growing cattle.

The nitrogen (N) fractions entering the intermediary metabolism consist of NH_3N absorbed from the rumen, dietary, microbial and endogenous amino acids (AA) absorbed from the small intestine, and NH_3N from the large intestine. The absorbed AAs are utilized for maintenance, growth, pregnancy and milk production. The efficiency of AA utilization is specific for each production/process. The metabolizable protein available for animal production is assigned as amino acids absorbed from the small intestine (AAT_N). The N which is not used for maintenance or production is excreted in the urine.

Predicting nutritive value is only one part of ration formulation as formulation involves both the selection of feed ingredients and the prediction of feed intake. Therefore, the NorFor system contains a module to predict the intake of feeds. For prediction of feed intake dietary fill values (FV) and animal intake capacity (IC) are applied. In roughages, FV is calculated from OM digestibility (OMD) and NDF content, and in ensiled forages the basic FV is also corrected for content of VFA, LAF and NH_3N. Animal IC is dependent on BW, milk yield, stage of lactation, lactation number, ADG and physical activity. The model uses a combination of dietary physical effects and metabolic factors to impact feed intake, and the effect of easily fermentable carbohydrates on roughage intake is accounted for by using a substitution rate factor (SubR).

A minimum amount of large particles is essential for optimal rumen function. Hence, a module to evaluate the physical structure of the diet is included in NorFor. The dietary physical effect is described by a total chewing index (CI), which is calculated as the sum of an eating (EI) and ruminating (RI) index for each individual feed. The EI value reflects the associated chewing activity as feed is consumed and is calculated from the particle length and NDF content of the feed. The RI value is calculated from particle length, NDF content and a hardness factor, which is dependent on the iNDF content of the feed. The hardness factor reflects the lignification of the structural fibre of the feed and the associated physical force required for the comminution of large particles.

The output from a model calculation in NorFor describes the intake of the individual feeds in the total ration. It consists of variables describing efficiencies of digestion and nutrient utilization, production (milk, ADG), N excretion, nutrient balances, energy (NEL or NEG) and protein (AAT_N) values of the ration.