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Scientific Expert Panel

Evaluation of the impact of nutrient digestibility conditions on pigs and poultry health and welfare

1. Introduction

This document is part of a set of documents developed by IFIF with the support of the IFIF Scientific Expert Panel and adopted by the IFIF Working Group (WG) on' Nutritional Innovation to Promote Animal Health'.

The IFIF WG was launched in 2017 with the objective to have '*animal nutrition solutions contributing to animal health and animal wellbeing* ***scientifically recognized, clearly understood,*** *and benefit from a proper regulatory* ***framework*** *to be valorized and implemented*'.

Nutritional solutions, now called nutritional strategies are aimed to support the development of animal adequate nutrition.

Adequate nutrition is defined as '*the oral intake of animals of adequate levels of nutrients, substances, microorganisms, and other feed constituents, considering their combination and presentation, necessary to fulfill functions related to their physiological states, including the expression of most normal behavior, and their resilience capabilities to cope with stressors of various type encountered in appropriate husbandry conditions.'* Furthermore, the way to achieve adequate nutrition is described as follows:

- *Optimization of feed composition, manufacturing, presentation, and delivery to animals,*
- *Minimization of the exposure of animals to stressors in feeds,*
- *Coverage of the animal's requirements for maintenance, activity, growth, production, and reproduction,*
- *Support of digestion and physiological functions, body systems, and behavioral expression.*

The purposes of these documents are to provide

- The developers of nutritional strategies with information on the way to evaluate the effectiveness of their strategy for a given purpose
- The evaluation bodies in the different jurisdictions with an approach for the evaluation of the effectiveness of nutritional strategies for a given purpose.

Each document will provide recommendations with a focus on a specific purpose, in relation with microbiome, gut function, exposure control, immunity, physiology, and others. The information provided in the document does not depend on a particular nutritional strategy and may be used to evaluate any nutritional strategy having an impact on nutrient digestibility.

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The present document is focusing on the evaluation of nutrient digestibility and its impact on animal health and welfare. It also considers the interaction between nutrients, such as protein and energy.

2. Scope

This document describes how nutrient digestibility affects the health and welfare of farm animals. The document, however, is not designed to elucidate the relationship between every nutrient and health or welfare in all animal species. It draws the link between nutrient digestibility and health as well as welfare in a general sense with specific examples of nutrients and health or welfare issues using the appropriate species of concern.

3. Descriptions of endpoints

Provision of adequate nutrition is the starting point for keeping animals healthy. A healthy animal, in turn, is likely to exhibit a good welfare status. It is expected that future animal enterprises will endeavor to address all three aspects, i.e., nutrition, health, and welfare, to satisfy the demand for sustainable and ethical food production.

All nutrients are required for one purpose or another for the animal, be it carbohydrates for energy; proteins for provision of amino acids for growth and body functions (MacDonald et al. 2011; Adedokun et al. 2011; Liu et al. 2013; Selle et al. 2013; Munyaka et al. 2016); or minerals for skeletal development and components of metal-containing proteins and hormones. In theory, any deficiency, however small that is, can affect health and hence welfare of the animal. The question is to what extent nutrient digestibility conditions can affect health and welfare of farm animals in an obvious and discernable manner and how it can be estimated under practical conditions?

This document, however, is not about providing an exhaustive list of nutrients and their relationship with health or welfare in all species of farm animals; rather it will endeavor to present well evidenced cases that make scientific and practical sense to the reader.

Protein digestion

Animal feed must contain proteins that supply amino acids for body tissue growth, reproduction, and components of key metabolites. Proteins come from a variety of sources, mainly plant and animal origin (including insects), although proteins produced from single cell organisms such as microorganisms and algae specifically grown for feed use are becoming increasingly common.

The challenge is that protein digestibility in pigs and poultry differs depending on the source of the ingredient, processing, storage, age of the animal to which it is fed, and technological treatment of the feed or the ingredient (Hughes and Choct, 1999; Rowe et al. 1999). It is well known that when protein digestibility is poor, amino acid deficiencies can occur, depressing performance and thriftiness of animals. In poultry, an excess amount of undigested protein reaching the hindgut causes the proliferation of proteolytic organisms (Pieper et al. 2016), which leads to health and welfare problems (See IFIF document on fermentation pathways and metabolites).

The health and welfare problems caused by poor digestibility of proteins include wet litter in poultry resulting in breast blister and hock burn, whilst a high concentration of ammonia resulting from the decomposition of N-rich compounds in the excreta can cause serious respiratory problems in both pigs and poultry (Elling-Staats et al. 2021; Gilbert et al. 2018). Furthermore, poor quality or

digestibility of proteins often acts as a predisposing factor for necrotic enteritis in meat chickens (Palliyeguru et al. 2009; Wu et al. 2014).

The protein digestibility value for feed depends largely on the protein sources used in the formulation and, to a lesser extent, the age of the animal in which the measurement is taken. For instance, the protein digestibility for casein is 98%, whereas that of rapeseed meal is around 70% in both poultry and swine. These two ingredients highlight the extremely wide range in protein digestibility values expected in monogastric animals fed commercial diets formulated using a variety of raw materials available across the world.

Carbohydrate digestion

Carbohydrates in feed consist of starch, non-starch polysaccharides (NSP, the main part of fibre) and low-molecular sugars such as oligosaccharides, disaccharides, and monosaccharides. The literature is awash with evidence showing that carbohydrate digestibility varies tremendously in pigs and poultry, depending on the ingredient source, the type of carbohydrates, i.e., starch vs NSP, age of the animal, processing, and the use of feed additives, such as enzymes. The link between carbohydrate digestibility and health or welfare of monogastric animals is very obvious.

The digestibility of NSP, for instance, is very low in poultry (Choct 2015) and is not high in pigs (Serena et al. 2009). Furthermore, NSP once solubilized, elevate digesta viscosity, leading to wet droppings and increased fermentation in the small intestine in chickens (Choct et al. 1996). Such changes in the gut make chickens more prone to diseases such as necrotic enteritis (Kaldhusdal and Skjerve 1996). Necrotic enteritis in its clinical form causes high mortality and in its subclinical form causes morbidity and welfare problems as well as massive economic losses to the farm. In pigs, poorly digestible carbohydrates such as NSP may play a role in the onset of post-weaning diarrhea, which is a major health and welfare issue in the swine industry (Pluske et al. 2001).

On the other hand, NSP may have positive impact on the gut microbiome. It depends very much on the type of NSP and whether or not appropriate carbohydrases are used in conjunction. For instance, dietary arabinoxylans contained in pig and poultry feed can be broken down by xylanase in situ, leading to the production of arabinoxylo-oligosaccharides or xylo-oligosaccharides (AXOS or XOS) (Morgan et al. 2019; Bautil et al. 2019). XOS are known to possess prebiotic activities by stimulating the beneficial gut microbiota and promoting production performance (Courtin et al. 2008ab; De Maesschalck et al. 2015).

There no such thing as a typical carbohydrate digestibility value because feed carbohydrates represent a diverse range of nutrients as outlined above. Usually, starch, as the main energy supplier of monogastric diets, typically has an apparent ileal digestibility value well above 95% and a total tract digestibility value above 98%. However, starch may be resistant to digestion in some feed ingredients. On the other hand, the digestibility of NSP is complex, depending on numerous factors: 1) the physiochemical structure of the NSP entity affects its digestibility. In general soluble NSP are better digested than insoluble NSP and low-molecular weight carbohydrates such as oligosaccharides and inulins are more digestible than large, cross-linked molecules, For instance, pigs, and poultry to an extent, can digest most oligosaccharides, pectins and soluble beta-glucans, especially with the aid of exogenous enzymes, whereas they are unable to digest much of lignocellulose compounds and insoluble mannans; 2) older animals are generally able to digest a higher proportion of NSP than younger animals; 3) in general pigs digest NSP better than poultry.

Mineral digestion

Animals require both macro and micro minerals in order to support their skeletal growth and numerous metabolic functions. Again, there is clear evidence that mineral digestion and absorption is of paramount importance for the health and wellbeing of all animal species. Poorly digestible P and Ca sources will cause tremendous damage to the animal's skeletal growth and many other metabolic functions; similarly, any issue with the digestibility or availability of trace mineral such as Cu, Zn, Fe and Mn will be detrimental to the performance, health, and welfare of all farm animals (Li et al. 2019; Manangi et al. 2012). For instance, the requirement for the trace mineral selenium is minuscule at 0.05mg/kg diet. However, if the requirement is not met, poultry will suffer from compromised immunity, reproductive functions, and production performance (Surai 2018). By extension, such animals cannot be said to enjoy a good health or welfare status.

Other nutrients

The digestibility and availability of nutrients such as fat and vitamins also have a marked influence on the performance, health, and wellbeing of animals.

4. Parameters for the evaluation of the endpoints

The endpoint "Nutrition Digestion and Absorption" is self-explanatory. But from a practical point of view, digestibility alone should be used to evaluate nutritional strategies, while absorption is difficult to determine even in sophisticated laboratories. For macro nutrients such as protein, carbohydrate, Ca, P, and fat, both faecal/excreta digestibility assays and ileal digestibility measurements using digesta markers can suffice for the purpose of identifying the link between digestibility and health/welfare, for micronutrients such as trace minerals and vitamins, digestibility trials are often not suitable and other techniques will have to be employed to check the status of these nutrients. When evaluating the digestion of micronutrients, the methods used should be properly described and the expected endpoint validated (e.g., bioavailability, tissue concentration).

Performance parameters, whilst the ultimate determinant of farm profitability, are often not appropriate for the evaluation of digestibility and absorption due to numerous other factors on farm that affect production performance (e.g., animal management, genetics, disease).

5. Methods to measure the parameters

There are well-established protocols for conducting digestibility studies in poultry (Bourdillon et al. 1990; Ten Doeschate et al 2007) and in pigs (Zhang and Adeola 2017; Patience 2016). A practical guideline for conducting nutritional experiments in pigs and poultry was published in a book with the same title with a comprehensive coverage of the topic (Bedford et al. 2016). One of the key elements when measuring the impact of a nutritional strategy on digestion is the appropriateness of the control, which should reflect usual practices on farm (such as composition of the feed, categories of animals)

Mateos et al. 2018 and Noblet et al. 2022 reviewed the methods of evaluation in depth including various limitations inherent to some of the techniques used to measure energy and certain nutrients.

There is a strong trend towards the development and use of *in vitro* techniques that can accurately and rapidly estimate nutrient contents as well as nutritive values (digestibility) (Zaefarian et al. 2021). There are two main drivers for this: 1) most *in vivo* techniques are expensive and are difficult to carry

out in farm settings, and 2) limitation on experimental use of animals is increasingly imposed due to animal welfare concerns and societal change at large.

There are a number of very good *in vitro* techniques that are universally used in research and industry alike. For instance, the near infrared reflectance spectroscopy (NIRS) technique is now widely used to determine the content of many nutrients and the nutritive value (digestibility, digestible energy and metabolizable energy levels).

6. Conclusions

The link between nutrient digestibility and health or welfare of pigs and poultry is clear, and it is practical to implement in most cases. The methods, including *in vitro* techniques, are well established and are reasonably straightforward to use them for the evaluation of the endpoints outlined in this document.

7. Abbreviations

NSP: non-starch polysaccharides

8. References

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9. Glossary of Terms

Endpoints: The measurable impact of a nutritional strategy on the animal, its physiology, or its microbiome.

Health: The state of normally functioning animal, especially the state of being sound, free from physical disease, pain or (symptom of) stress.

Welfare: The physical and mental state of an animal in relation to the conditions in which it lives and dies.