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Optimizing broiler nutrition and feed formulation strategies: A comprehensive review for the Nigerian poultry industry

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Abstract
This literature review delves into the critical aspects of broiler nutrition and commercial feed production, with a particular focus on the Nigerian poultry industry. The study explores the various types of commercial diets used in broiler farming, including starter, grower, finisher, economy, and premium diets, each tailored to meet specific growth stages and economic considerations. The nutrient composition of these diets is examined in detail, covering protein, energy, minerals, and vitamins.
The review underscores the importance of formulating diets for broilers, emphasizing the ability to customize nutrient compositions according to the changing requirements of broilers during different growth phases. This flexibility also enables the incorporation of cost-effective, locally available ingredients without compromising on nutrient quality.
Furthermore, the paper discusses the significance of nutrient utilization and digestibility in broiler nutrition, shedding light on the digestive physiology of broilers and factors influencing nutrient absorption and utilization. Age, sex, feed intake, and feed composition are among the factors explored in this context.
Overall, this comprehensive review provides valuable insights into the intricacies of broiler nutrition and commercial feed production, offering a foundation for optimizing broiler growth and minimizing production costs in the dynamic landscape of the Nigerian poultry industry.

Keywords: Broiler nutrition, feed formulation, Nigerian poultry industry, sustainable poultry farming, feed challenges and solutions

Introduction

Commercial feed production (world view)

The Alltech Global Feed Survey, initiated in 2011 to enhance the understanding of global feed volume and production trends, has now amassed four years of data, offering a more accurate depiction of the current state of the feed industry. The global supply of complete feed has risen to 980 million tonnes, valued at $460 billion, compared to 873 million tonnes valued at $350 billion in the inaugural study conducted in 2011 [1]. Various challenges such as droughts, floods, high raw material costs, animal diseases, and fluctuations in governance import/export regulations have constrained the industry's growth in the latter part of this four-year period [2].

Asia remains a dominant force in global feed production, contributing to over a third of the total supply. Although Asia was previously one of the fastest-growing regions, its growth has now moderated. Globally, the number of feed mills is estimated to be around 31,000, with Asia and North America collectively accounting for more than half of this figure. Africa and, more recently, Latin America have emerged as the fastest-growing regions in terms of both feed mill numbers and feed tonnage [3].

The Middle East, on the other hand, has the greatest average feed mill size, generating almost 63,000 tonnes per year on average [4-5]. China, Brazil, India, and Russia (BRIC) have significantly influenced the feed industry, collectively increasing production by 33 million tonnes by 2012 [6].

India, in particular, has experienced substantial growth, propelled by a favorable climate and innovative practices. Beyond the BRIC countries, Turkey, Indonesia, and Romania have garnered attention due to substantial production increases in 2014.

China leads the world in overall feed tonnage by a considerable margin, but the country's feed industry has witnessed a decline in both feed mills and tonnage since 2013. This decline is attributed to the government's preference for consolidation to enhance traceability.

Analysts suggest that reduced consumer demand, influenced by a slower pork market and avian flu, contributes to this trend [1]. These circumstances underscore the increasing emphasis on food safety and quality in China.

The United States and Brazil consistently hold the second and third positions in feed production, producing 172 and 66 million tonnes, respectively. Poultry maintains its dominance in the industry, commanding 44-46 percent of the feed market share, driven by factors such as taste, perceived healthiness, cooking flexibility, religious preferences, and cost-effectiveness. Despite escalating raw material prices, pig feed production has steadily increased since 2011. Conversely, the market share for ruminants has declined over this period. The evolving dynamics highlight the critical role of animal feed in the global food chain, now recognized as a shared global value and responsibility.

Nigeria Poultry Industry

Poultry production holds a dominant position among various livestock activities in Nigeria, evident by its widespread presence across the country [7]. This form of livestock management has transitioned from a backyard pastime to a thriving commercial venture. Its distinctive feature lies in its rapid turnover and prompt returns on investment within the livestock sector. According to Anosike *et al*. [8]. Nigeria witnessed the production of 2 billion eggs and 12,000 tonnes of poultry meat in 2018, with an estimated per capita consumption of poultry meat at 1.3 kilograms. Poultry, ranking second only to ruminants as a protein source in Nigeria, contributes to more than a quarter of the country's total meat production [8]. The poultry industry grows at a quicker rate than other agricultural livestock industries in terms of consumption and trade volume. Chickens (local chickens, broilers, and layers), turkeys, geese, ducks, guinea fowls, and pigeons are among the several species used in poultry production. Despite Nigeria's fast-growing trade and prominence in chicken production, the country is not without its issues. Chickens are the most numerous, common, and extensive animal farmed in Nigeria, yet Nigeria has the lowest meat and egg consumption rates, at.8.1 and 3.5kg, respectively [7].

Challenges of Poultry Production in Nigeria

While poultry production holds a prominent position in the livestock industry, it is not exempt from challenges. The complexities and obstacles associated with poultry production in Nigeria are formidable and should not be underestimated. The industry's output pace has slowed as a result of these issues. Rabana *et al*., [9] indicated a high rate of disease and insect infestations as a major difficulty in chicken production. Different studies have highlighted a lack of access to loan and credit procurement [8]; Masud *et al*., [10]. Lack of technical knowledge was also mentioned by Adeyemo & Onikoyi [11], as a problem in the industry. They claim that most people get into poultry farming because they see others making a lot of money, but they fail to inquire about the necessary knowledge involved in poultry production. Ipara *et al*., [12]; Muhammad *et al*., [14] cited high mortality as a major concern facing the sector, which they claim is related to the supply of low quality chicks, as documented by Anosike *et al*., [8]; Adeyonu *et al*., [13]. According to Muhammad *et al*., [14], most farmers have no idea which farms hatch the chicks they buy from roadside hawkers because they buy from roadside hawkers. Mortality is most common during the brooding stage, according to Anosike *et al*., [8] noted the high cost of poultry feeding. Inadequate poultry extension services, according to Egbeadumah *et al*., [15], is one of the poultry industry's significant concerns. Anosike *et al*., [8] and Muhammad *et al*., [14] identified insufficient access to and high costs of veterinary services as another important concern facing the sector.

Possible Solutions to the Challenges of Poultry Production in Nigeria

Despite the challenges faced by the poultry industry in Nigeria, it continues to function, albeit at a reduced production rate. Addressing these issues is not beyond reach. A significant issue in Nigeria's chicken industry is the frequent outbreak of diseases. The authors suggest that veterinary intervention is essential to minimize losses associated with these diseases [8].

To enhance chicken output in Nigeria in the short term, implementing strategies such as brood feeding guidance and basic disease management programs is crucial. Extension services must provide poultry producers with technical expertise to boost chicken production. Therefore, in line with the authors' suggestions, extension workers play a pivotal role in improving rural poultry production [8].

Adeyonu and Odozi [16], in their research on small poultry farms in Ibadan, Oyo State, recommend encouraging small-scale layer poultry farmers to form cooperative societies or join existing ones. This would facilitate their access to loans for business development. Additionally, the authors propose that the government should allocate funds to support poultry farmers. They emphasize the need for capacity training to help farmers overcome challenges in modern poultry farming and advocate for the commercialization of small-scale layer poultry production. This aligns with the advice of Hafez and Attia, [17] who suggest that the government should provide financial assistance in the form of soft loans to subsistence and small-scale chicken farmers. According to Hafez and Attia, this measure can prevent the sector's decline due to unproductive operations or an increase in the price of poultry products. To minimize mortality rates, Anosike *et al*., [8] recommend that relevant organizations inspect the hatchery sector to ensure the production of healthy day-old chicks under optimal sanitary conditions.

Feeding in Broiler Bird Meat Production

Over 70% of the expenses associated with chicken meat production are attributed to feed costs. Therefore, the utilization of high-quality feed becomes crucial to enhance birds' performance, thereby improving feed efficiency, and subsequently, the overall performance and profitability of broiler chicken farming. The advent of modern PC feed definition tools has made achieving precise nutritional goals a feasible objective, allowing different limitations to be examined, such as the nutritive nature of feed and feed fixings, as well as budgetary factors [18].

The scale of the activity and the surrounding environment determine the best way to manage the program. The time and feed required to produce broiler meat are constantly decreasing due to genetic and economic improvement [22] As a result, the starter time frame now covers a much larger portion of the development cycle, emphasizing the importance of a good starter diet. It has a broad impact on the business as a whole, as well as the execution process [19].

As a result, deciding on a monetary strategy for poultry is important, and little improvements in existing animal production practices could result in big investment revenues when multiplied by the large volumes produced by poultry companies [20]. Broiler chickens are typically raised in different stages, known as starter, grower, and finisher phases, to provide them with the appropriate nutrition needed for their growth and development. Each phase requires a specific type of feed that is formulated to meet the bird's nutrient requirements at that particular stage of life [21]. As a result, it implies that birds of a certain age are cared for at varying nutritional requirement, based only on economic considerations. NRC [21]. Proposed that dietary amino acid requirements be divided into three periods: starter (0 to 3 weeks old enough), grower (3 to about a month and a half old enough), and finisher (6 to about two months old enough). Nonetheless, because the starter feed is the most expensive in the broiler maintenance program, the review's focus is on reducing starter ration while simultaneously increasing agricultural productivity. Because the cost of feed reduces as the protein level decreases, the best time to switch diets is an economic consideration.[23] When faced with increased feed costs and growing feed input costs, the first instinct is to look for ways to offset the financial impact on the business by lowering the nutritional specific of the feed to lower feed cost per ton [24]. Nonetheless, because the starter feed is the most expensive in the broiler maintenance program, the review's focus is on reducing starter ration while simultaneously increasing agricultural productivity. Because the cost of feed reduces as the protein level decreases, the best time to switch diets is an economic consideration [23]. When faced with increased feed costs and growing feed fixed costs, the first instinct is to look for ways to offset the financial impact on the business by lowering the nutritional specific of the feed to lower feed cost per ton. Early nutrition may appear to play an important role in the development and benefit of poultry [25]. Giving the perfect nourishment during the early period of development can have a significant impact on the final bird's performance. However, ecological factors such as bird genetic traits, animal welfare, and the climate the birds are exposed to over the course of the animal lifecycle can also influence the cost of production. This vast number of factors can have an impact on bird performance, resulting in lower monetary returns when the birds arrive at the market. The review was then conducted in order to determine the effects of altering the starter and finisher dietary stages on broiler development.

Phase feeding

Only a few growth phases are mentioned in current poultry recommendations; meat birds are examined in three phases: up to three weeks, three to six weeks, and six to about two months. Grow-out periods, on the other hand, could last anywhere from four to ten weeks, depending on market demand. To improve performance and profit margins, the commercial chicken business is increasingly using phase-feeding systems, knowing that nutritional needs are more dynamic than these basic ideas. When different diets are developed to fit changing needs and cost, dietary protein and amino acid requirements are often reduced over time [21, 26].

Pre-starter, starter, grower, finisher, and withdrawal; or pre-starter, starter, grower, finisher, and withdrawal; or pre-starter, starter, grower, finisher, and withdrawal; or pre-starter, starter, grower, finisher, and withdrawal. Withdrawal diets are commonly supplied during the last seven to ten days of growth and include the exclusion of such pharmacological elements as well as a reduction in protein/amino acids. In recent years, they have also involved the loss of several vitamins and trace minerals, as well as increased energy use [27].

Types of phase feeding

Single Phase Feeding: This entails the use of a single feed type throughout the unit production cycle of broiler meat birds, it could be a starter alone through the cycle or a modified feed. Many researchers have tried to use other phases throughout but the most effective has been the starter phase due to its richness in nutrients and ability to the important nutrient requirement of the animal at every phase and encourage the development of economic traits with its downside in excessive protein and lower calcium level for bone formation at other phases.

Double Phase Feeding: This entails the use of two feed types through the production phase of broiler bird production, an instance as starter and finisher only and it is quite the commonest feeding plan where the birds are raised on starter for the first three weeks of life and finisher for the next two to three week depending on the target market weight and animal performance

Three Phase Feeding: This entails the use of three feed types in the production cycle of broiler bird and it entails the use of starter feed for 3 weeks, a grower for two weeks, and finisher 3 weeks for a total of 8 weeks or two months production cycle, it used to be the commonest but it is soon replaced by the two-phase feeding as most farmer simply skips the grower phase, as it is less time and cost-effective.

Broiler Nutrition

A broiler chick weighing 40 g at hatching can grow to more than 4000 g within 8 weeks. However, such rapid growth cannot be sustained without equally significant increases in the functional capabilities of the heart and lungs [28]. Modern broiler chickens achieve exceptional growth rates thanks to remarkable advancements in genetics and nutrition over the past 40 years [29].

Providing immediate access to feed has been shown to benefit broiler chicks. Although energy has traditionally been the main focus of nutrition, a more balanced nutrient profile, particularly regarding protein and amino acids, would be beneficial for chicks. Meeting the demand for meat production has resulted in modern broilers reaching market age at an accelerated pace, making advancements in nutrition crucial for sustainable production [30]. Therefore, nutritionists are turning their attention to immuno-nutrition, among other specialized areas [31]. In formulating broiler diets, particular attention is given to crude protein (CP), a crucial component in poultry nutrition, alongside carbohydrates, fat, water, vitamins, and minerals [32]. Proteins, comprising α-amino acids interconnected by peptide bonds, undergo hydrolysis in the digestive system to generate amino acids. These amino acids are subsequently synthesized and metabolized to produce the proteins essential for constructing various body tissues [33].

Moreover, proteins play vital metabolic functions, acting as blood plasma proteins, enzymes, hormones, and antibodies [34]. However, protein is among the most expensive ingredients in poultry diets, making efficient protein usage necessary for both nutritional and economic reasons [35].

Protein is a crucial component of biologically active compounds in the body, including enzymes and hormones. As a result, protein products are of great interest in poultry nutrition. Meeting broilers' high dietary protein requirements requires a thorough understanding of their protein and amino acid needs and how they impact growth performance and development [36-37]. Additionally, knowledge of available protein sources is critical. Emphasis is placed on minimizing anti-nutritional factors and supplementing immunologically active compounds to promote gut health [38]. Diet composition and processing also influence these characteristics.

Broiler Nutritional Requirement

Broilers require a balanced diet to support their rapid growth and development. The nutritional requirements of broilers vary depending on their age, weight, and sex, as well as environmental factors such as temperature and humidity [39-40]. The major nutrients required by broilers include energy, protein, amino acids, minerals, and vitamins.

Energy is the most critical nutrient for broiler growth, and it is typically provided in the form of grains and fats. Protein is essential for muscle development and repair, and it is commonly supplied through sources such as soybean meal and fishmeal. Amino acids, the building blocks of protein, are also crucial for broiler growth and development, with lysine being the most limiting amino acid in most diets [21, 41].

Minerals such as calcium, phosphorus, and sodium are necessary for bone and muscle development, as well as other physiological functions. Vitamins are also important for various metabolic processes and immune function.

Optimizing the nutritional composition of broiler diets is critical for achieving maximum growth and production while minimizing feed costs and environmental impacts [35]. In recent years, there has been a growing interest in formulating diets using alternative protein and energy sources, such as insects, algae and by-products from food and biofuel production [42]. A better understanding of the nutrient utilization and digestibility of these alternative ingredients could lead to more sustainable and cost-effective broiler diets [43].

Importance of Feeding Broilers with Balanced Diet

Early access to feed and water is crucial for maximum gut development in broiler chicks, as reported by Li *et al*., [44]. Delayed feeding leads to weight loss and lower metabolic rates, which may result in poor flock uniformity and increased mortality [45]. Providing chicks with nutrients and energy from feed and water immediately after placement enables them to actively utilize the absorbed nutrients and antibodies from the yolk for overall development [45]. Mortality peaks around 3-4 days of age, which could be due to the yolk sac not being absorbed.

Optimal feed and water intake is necessary to prevent increased mortality and poor uniformity, which can be achieved by monitoring crop fill and live weight. A recommended seven-day weight of around 180g, or 4-5 times the weight of the day-old chick, ensures maximum gut and organ development for improved performance and body composition. Proper brooding conditions, including recommended temperature, relative humidity, and ventilation, are essential for stimulating feed and water intake. Observing chick behavior and conditions in the house is critical for ensuring that all chick needs are being met [46].

Feeding broilers with a balanced diet that meets their nutrient requirements is crucial for optimal growth and performance. A diet that is deficient in any essential nutrient can result in poor growth, reduced feed efficiency, and increased susceptibility to disease [21]. On the other hand, overfeeding certain nutrients can lead to metabolic disorders and other health problems. Therefore, a balanced diet that provides the appropriate levels of energy, protein, amino acids, vitamins, minerals, and other essential nutrients is necessary for maximizing broiler growth and performance while minimizing health risks [31].

Factors Affecting Nutrient Utilization and Digestibility in Broilers

In addition to feeding broilers with a balanced diet, the digestibility and utilization of nutrients can be affected by several factors. One important factor is the age of the bird, as the digestive capacity and nutrient requirements change as the bird grows. Another factor is the composition of the diet, such as the type and level of protein, fat, and fiber, as well as the presence of anti-nutritional factors. The processing of feed, such as pelleting, can also impact the digestibility of nutrients. Other factors include the health status of the bird, environmental factors such as temperature and humidity, and management practices such as feeding and watering strategies. Understanding these factors and their interactions can help optimize nutrient utilization and digestibility in broilers [47].

Table 1: Broiler Nutritional Requirement

Characteristic	Broiler Pre-starter	Broiler Starter	Broiler Finisher
Moisture, % (Max.)	11.00	11.00	11.00
Crude Protein, % (Min.)	23.00	22.00	20.00
Crude fibre, % (Max.)	5.00	5.00	5.00
Acid insoluble ash, % (Max.)	2.50	2.50	2.50
Salt, % (Max.)	0.50	0.50	0.50
Calcium, % (Min.)	1.0	1.0	1.0
Phosphorous (Available), % (Min.)	0.45	0.45	0.45
Linoleic Acid, % (Min.)	1.00	1.00	1.00
Lysine, % (Min.)	1.30	1.20	1.00
Methionine, % (Min.)	0.50	0.50	0.45
Meth. +cystine, %	0.90	0.90	0.85
Metabolizable Energy (Kcal/Kg) Min.	3000	3100	3200
Ether extract, % (min.)	3.0	3.5	4.0

***Source*:** Nutrition Requirements of Meat Chickens (Broilers) - Poultry Hub Australia, 2020

Commercial Diets for Broilers

The Nigerian poultry industry relies heavily on broiler production, playing a pivotal role in supplying substantial animal protein to the population. Achieving success in broiler farming hinges on essential factors, with proper nutrition standing out. This entails delivering a well-balanced diet tailored to meet the distinct nutritional needs of the birds throughout various stages of growth. Commercial diets are widely used by broiler farmers in

Nigeria, and they come in different classes based on their nutrient composition and cost [48].

Types of Commercial Diets for Broilers in Nigeria

a) **Starter diets:** These are feeds formulated for the first 3-4 weeks of broiler growth, and they typically contain high levels of protein, energy, and amino acids to support rapid growth and development [49].
b) **Finisher diets:** These are feeds formulated for the last 3-4 weeks of broiler growth, and they typically contain lower levels of protein and higher levels of energy to promote weight gain and fat deposition [50].
c) **Grower diets:** These are feeds formulated for the intermediate period between starter and finisher stages, and they contain a balanced combination of protein, energy, and other nutrients to support moderate growth and development [26].
d) **Economy diets:** These are feeds formulated with low-cost ingredients and lower nutrient density, and they are often used by small-scale farmers with limited resources [51].
e) Premium diets: These are feeds formulated with high-quality ingredients and higher nutrient density, and they are often used by large-scale farmers or those who prioritize performance over cost [52].

Nutrient Composition of Commercial Diets for Broilers in Nigeria

a) **Protein:** Broilers require high levels of dietary protein for muscle growth, and commercial diets typically contain 20-25% crude protein (CP) for starter diets, 18-22% CP for grower diets, and 16-18% CP for finisher diets. Economy diets may contain lower levels of protein (12-16% CP), while premium diets may contain higher levels of protein (25-30% CP) [53].
b) **Energy:** Broilers require a high-energy diet for growth and maintenance, and commercial diets typically contain 3000-3200 kcal/kg metabolizable energy (ME) for starter diets, 3100-3300 kcal/kg ME for grower diets, and 3200-3400 kcal/kg ME for finisher diets [54]. Economy diets may contain lower energy levels (2500-2800 kcal/kg ME), while premium diets may contain higher energy levels (3400-3600 kcal/kg ME).
c) **Minerals:** Broilers require adequate levels of calcium, phosphorus, and other minerals for bone formation and other physiological functions. Commercial diets typically contain 0.9-1.2% calcium and 0.4-0.6% phosphorus for starter diets, 0.8-1.0% calcium and 0.35-0.5% phosphorus for grower diets, and 0.7-0.9% calcium and 0.3-0.4% phosphorus for finisher diets. Economy diets may contain lower levels of minerals, while premium diets may contain higher levels of minerals and other micronutrients [50].

Formulated Diets for Broilers

Formulated diets are diets made by mixing various ingredients in specific proportions to meet the nutrient requirements of broilers. The ingredients typically include grains, oilseeds, animal protein sources, mineral supplements, and vitamin supplements. The advantage of using formulated diets is that farmers have more control over the nutrient content of the diet, allowing them to tailor the diet to the specific needs of their broilers [40].

Formulating a diet requires knowledge of the nutrient requirements of broilers at different stages of development. Factors such as age, body weight, sex, and activity level can all affect nutrient requirements. In addition, the nutrient content of the ingredients used in the diet can vary, so it is essential to regularly test the nutrient content of the diet to ensure that it meets the broilers' needs [21].

Importance of Formulating Diets

Formulating diets for broilers is crucial in ensuring optimal growth and development, as well as minimizing the risk of nutritional deficiencies and excesses. It involves the precise calculation and mixing of ingredients to provide the necessary nutrients for the birds to meet their requirements for maintenance, growth, and production [26].

One of the main advantages of formulating diets is the ability to tailor the nutrient composition to meet the specific requirements of broilers at different stages of growth. As broilers mature, their nutritional needs change, with higher requirements for protein, energy, and certain vitamins and minerals. Formulating diets that meet these changing needs can optimize growth and performance while minimizing the risk of excess or deficiency.

Another advantage of formulating diets is the ability to incorporate alternative or less expensive feed ingredients without compromising nutrient quality. This is particularly important in countries where feed ingredients may be scarce or expensive. By using locally available ingredients and formulating diets that meet the specific nutrient requirements of broilers, producers can lower feed costs without sacrificing the quality of the feed [55].

Furthermore, formulating diets allows for greater control over nutrient digestibility and utilization. By selecting ingredients based on their nutrient composition, digestibility, and availability, diets can be formulated to optimize nutrient absorption and utilization by the bird. This can lead to better growth rates, feed conversion efficiency, and meat quality [56].

Nutrient Utilization and Digestibility of Broiler

Nutrient utilization and digestibility are essential aspects of broiler nutrition as they determine the bird's ability to convert feed into body mass. Poor nutrient utilization and digestibility can lead to reduced feed efficiency, slower growth rates, and increased production costs. Therefore, it is important to understand the factors affecting nutrient utilization and digestibility in broilers to optimize their growth and minimize production costs [57].

The digestive physiology of broilers is essential for understanding nutrient utilization and digestibility. Broilers have a monogastric digestive system, which includes the crop, proventriculus, gizzard, small intestine, and large intestine. The crop serves as a storage organ for feed, while the proventriculus secretes hydrochloric acid and pepsinogen, which initiate protein digestion. The gizzard is a muscular organ that grinds and mixes feed particles to increase surface area for enzymatic digestion. The small intestine is where most nutrient digestion and absorption occur. The duodenum, jejunum, and ileum make up the small intestine, with the duodenum being responsible for the digestion of lipids, carbohydrates, and proteins [58].

The pancreas and liver play a significant role in digestion by secreting digestive enzymes and bile, respectively. The pancreas secretes enzymes such as amylase, lipase, and protease to aid in the digestion of carbohydrates, lipids, and

proteins, respectively. Bile is produced by the liver and stored in the gallbladder, which aids in the emulsification and absorption of lipids.

The large intestine is responsible for the absorption of water and electrolytes, as well as the synthesis of some vitamins and fermentation of undigested feed particles. The ceca, which are present in the large intestine, are responsible for the fermentation of indigestible feed particles and the synthesis of some vitamins.

Factors such as age, sex, feed intake, and feed composition can affect the digestive physiology of broilers. For instance, young broilers have a relatively underdeveloped digestive system compared to older birds, which affects their nutrient utilization. Additionally, high levels of dietary fiber can lead to reduced digestibility of other nutrients, while low levels of essential nutrients can limit their availability for absorption.

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