TECHNICAL BULLETIN

COMPOSITION AND QUALITY OF ALTERNATIVE PROTEIN INGREDIENTS FOR PET FOOD

KEY POINTS

- Data from ADM OutsideVoice℠ revealed that 49% of adults fall into the flexitarian category with health being the primary driver of their food choices.
- A series of research studies were conducted to evaluate the protein quality of a variety of popular alternative protein sources for dogs and cats: yellow peas, green lentils, black bean grits, navy bean powder garbanzo beans, pea protein, soy protein concentrate, soy flakes, soybean meal, peanut flour, corn gluten meal, potato protein, and Versity® dried yeast.
- The results of this research provides much needed information for pet food ingredient suppliers, manufacturers and formulators about the nutrient composition and biological availability of plant and yeast protein sources.

Traditional protein sources commonly used in pet foods include animal proteins derived from fresh meat and rendered meat meals. In recent years, consumer demand and the humanization of pets has driven the need for pet food manufacturers to use novel proteins from animal and plant sources. However, with protein supply increasingly becoming a global issue, alternative protein sources are now important factors in the sustainability of the global food system for people and pets. Plant- and yeast-based proteins are sustainable options that can be used in pet food and treats to supplement or replace animal protein ingredients.

The pet food industry is continually challenged with predicting future trends and product needs based on the ever-changing expectations of pet parents. Trends within the human food industry are often used to predict future opportunities in the pet food market. One emerging trend is the flexitarian dietary pattern. Flexitarians are consciously reducing, but not necessarily eliminating, meat and other animal proteins in their diet and replacing them with plant-based proteins. This flexitarian lifestyle is a food trend that is starting to increase demand for alternative, non-animal protein ingredients in pet foods.

OutsideVoice℠ is a proprietary consumer research tool used by ADM to quickly gain insights about the attitudes, preferences and behaviors of today's consumers. Data from OutsideVoice℠ revealed that 49% of the 5,000 adult (18+ years) respondents fall into the flexitarian category with health being the primary driver of their food choices. Many pet parents are flexitarians who want their dogs and cats eating similar foods as them. However, given that health is a key factor in choosing a flexitarian diet, pet parents need to be reassured that alternative protein sources are also healthy and safe for pets. For this reason, ADM completed a series of research studies in partnership with the Companion Animal Nutrition program at the University of Illinois Urbana-Champaign to evaluate the nutritional value of various non-animal protein sources.[1-3] This information will help the pet food industry understand how alternative, non-animal protein sources can be used effectively to meet the nutritional requirements of dogs and cats.

Nutritional Composition of Plant-Based and Yeast Protein Sources

The first step to gaining a better understanding of using plant-based and yeast protein sources in pet food formulations is to have a thorough understanding of their macronutrient, energy and amino acid composition. For this research, a variety of popular alternative protein sources were selected for characterization representing pulses (yellow peas, green lentils, black bean grits, navy bean powder and garbanzo beans), legume-based concentrates (pea protein, soy protein concentrate, soy flakes, soybean meal, and peanut flour), and non-legume sources (corn gluten meal, potato protein, and Versity dried yeast; Saccharomyces cerevisiae) (Table 1).

Table 1. Classification of alternative protein sources

Pulses	Yellow peas Green lentils Black bean grits Navy bean powder Garbanzo beans
Legume-based concentrates	Pea protein Soy protein concentrate Soy flakes Soybean meal Peanut flour
Non-legume sources	Corn gluten meal Potato protein Versity dried yeast

Table 2. Proximate analysis and energy content of various alternative proteins for pet foods and treats

INGREDIENT	Dry Matter %	Protein %	Fat %	Ash %	TDF %	GE (kcal/g)	TMEn (kcal/g)
Pulses		DRY MATTER BASIS					
Yellow peas	90.5	22.2	2.1	2.9	34.6	4.29	3.07
Green lentils	89.6	27.2	2.6	2.8	34.7	4.36	3.24
Black bean grits	92.4	20.8	2.9	3.9	29.1	4.47	3.10
Navy bean powder	92.3	20.8	3.6	3.5	29.3	44.44	3.20
Garbanzo beans	91.7	22.6	5.4	3.4	33.4	4.64	3.56
Legume-based concentrates							
Pea protein	91.0	55.1	5.0	5.9	22.7	4.80	3.25
Soy protein concentrate	94.3	72.3	1.1	6.6	31.9	4.74	2.72
Soy flakes	93.7	59.5	3.1	6.7	23.8	4.59	2.28
Sobean meal	90.1	52.7	3.2	7.5	30.3	4.68	2.89
Peanut flour	98.8	48.6	26.1	3.7	17.7	6.12	4.58
Non-legume sources							
Gluten corn meal	92.0	67.5	9.1	3.7	20.2	5.67	4.30
Potato protein	90.6	80.8	3.1	2.4	30.6	5.46	4.22
Versity dried yeast	92.8	52.4	15.7	3.7	38.3	5.64	3.61

TDF, total dietary fiber
GE, gross energy measured using bomb calorimetry
TMEn, true metabolizable energy corrected for nitrogen measured using cecectomized rooster assay

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Figure 1 is a visual comparison of the nutrient composition of the protein sources. Whole pulses were lower in protein ranging from 20.8 – 27.2% on a dry matter basis (DMB), while the concentrated protein sources that have been subjected to processing contained higher protein levels (48.6 – 80.8% DMB). Peanut flour and Versity were the highest sources of fat (15.7 – 26.1% DMB). Versity, green lentils, yellow peas and garbanzo beans had the highest levels of dietary fiber (33.4 – 38.3% DMB). These data show that each protein source has a unique nutritional composition, offering flexibility for pet food formulators trying to achieve specific nutritional targets.

Figure 1. Relative nutrient composition of alternative protein sources

	Protein	Fat	Ash	Gross Energy	Total Dietary Fiber
HIGHER	Potato Protein Soy Protein Concentrate Corn Gluten Meal	Peanut Flour Dried Yeast (Versity)	Soybean Meal Soy Flake Soy Protein Concentrate Pea Protein	Peanut Flour Corn Gluten Meal Dried Yeast (Versity) Potato Protein	Dried Yeast (Versity) Green Lentils Whole Yellow Peas Garbanzo Beans
	Soy Flake Pea Protein Soybean Meal Dried Yeast (Versity) Peanut Flour	Corn Gluten Meal Garbanzo Beans Pea Protein Navy Bean Powder	Black Bean Grits Corn Gluten Meal Dried Yeast (Versity) Peanut Flour Navy Bean Powder Garbanzo Beans	Pea Protein Soy Protein Concentrate Soybean Meal Garbanzo Beans Soy Flake	Soy Protein Concentrate Potato Protein Soybean Meal Navy Bean Powder Blackbean Grits Soy Flake
LOWER	Green Lentils Garbanzo Beans Whole Yellow Peas Black Bean Grits Navy Bean Powder	Soybean Meal Soy Flake Potato Protein Black Bean Grits Green Lentils Whole Yellow Peas Soy Protein Concentrate	Whole Yellow Peas Green Lentils Potato Protein	Black Bean Grits Navy Bean Powder Green Lentils Whole Yellow Peas	Pea Protein Corn Gluten Meal Peanut Flour
GROUPINGS	67.5 - 80.8%	15.7 – 26.1%	5.9 – 7.5%	5.5 – 6.1 kcal/g	33.4 – 38.3%
	48.6 – 59.5%	3.6 – 9.1%	3.4 – 3.9%	4.6 – 4.8 kcal/g	23.8 – 31.9%
	20.8 – 27.2%	1.1 – 3.2%	2.4 – 2.9%	4.3 – 4.5 kcal/g	17.7 – 22.7%

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FOCUS ON AMINO ACIDS

Dogs and cats do not have a specific nutritional requirement for protein. Instead, they require the essential amino acids contained in dietary proteins. Amino acids are the building blocks of body proteins and are classified as either essential or non-essential. Essential, or indispensable, amino acids must be obtained from dietary sources because the body cannot synthesize them to meet requirements. In contrast, nonessential, or dispensable, amino acids can be produced by the animal to meet requirements. During digestion, ingested dietary proteins are broken down into component amino acids and peptides, which are absorbed and then reassembled into proteins the animal requires for tissue maintenance, growth and/or reproduction. The amino acid composition of the select protein sources are shown in Table 3. As expected, whole pulses and the legume-based concentrates had the lowest levels of methionine, whereas Versity, corn gluten meal, and potato protein had the highest levels. Soy protein concentrate, Versity and potato protein had the highest levels of lysine which, in addition to methionine, is often a limiting amino acid in dog and cat food formulations.

INGREDIENT	Arg	His	Lle	Leu	Lys	Met	Phe	Thr	Trp	Val	Ala	Asp	Cys	Glu	Gly	Pro	Ser	Tyr
Pulses									DRY MATTER BASIS									
Yellow peas	1.82	0.56	1.04	1.66	1.77	0.23	1.13	0.85	0.17	1.17	1.01	2.62	0.36	3.78	1.03	1.07	0.88	0.72
Green lentils	2.00	0.64	1.18	1.89	1.82	0.21	1.30	0.89	0.10	1.32	1.08	3.03	0.27	4.08	1.11	1.09	1.05	0.74
Black bean grits	1.25	0.66	1.15	1.85	1.63	0.28	1.35	1.02	0.25	1.36	1.00	2.73	0.24	3.26	0.96	1.05	1.09	0.69
Navy bean powder	1.16	0.63	1.08	1.75	1.55	0.23	1.26	0.96	0.26	1.30	0.95	2.58	0.27	3.07	0.92	0.99	1.06	0.65
Garbanzo beans	2.31	0.58	1.04	1.64	1.56	0.33	1.32	0.76	0.20	1.07	0.96	2.54	0.34	3.63	0.92	1.04	0.91	0.60
Legume-based concentrates																		
Pea protein	4.89	2.57	91.0	4.10	4.21	0.49	2.77	1.91	0.48	2.81	2.31	6.32	0.64	8.93	2.35	2.47	2.01	1.76
Soy protein concentrate	5.36	3.62	94.3	5.68	4.73	1.06	3.71	2.75	0.89	3.84	3.13	8.34	1.04	13.42	3.11	3.89	2.90	2.51
Soy flakes	4.29	2.93	93.7	4.58	3.77	0.81	3.07	2.17	0.8	3.08	2.52	6.72	0.85	10.72	2.56	3.15	2.24	2.13
Sobean meal	3.84	2.57	90.1	4.04	3.44	0.75	2.64	2.03	0.73	2.72	2.30	6.06	0.79	9.76	2.34	2.74	2.46	1.84
Peanut flour	4.82	1.72	98.8	3.07	0.94	0.50	2.44	1.16	0.56	2.11	1.86	5.39	0.50	8.79	2.75	2.11	1.72	1.76
Non-legume sources																		
Gluten corn meal	2.34	2.96	92.0	11.04	1.25	1.75	4.31	2.17	0.43	3.29	5.80	4.21	1.25	14.28	1.98	6.16	2.68	3.46
Potato protein	4.11	4.83	90.6	8.39	6.51	1.85	5.29	4.54	0.74	5.83	3.93	10.28	1.25	8.73	4.08	4.21	3.45	4.27
Versity dried yeast	2.33	2.71	92.8	5.49	3.01	1.05	2.73	2.15	0.52	3.12	3.49	4.46	0.66	7.22	2.21	3.11	2.01	2.03

PROTEIN QUALITY

Simply knowing the protein and amino acid composition of a dietary protein source is insufficient for understanding its nutritional value to the dog or cat. Full understanding requires an assessment of protein quality, or the ability of the protein source to meet the essential amino acid requirements of the animal. There are a number of methodologies for determining protein quality of ingredients and foods. The protein efficiency ratio (PER) was the first method developed for assessing protein quality for human foods. It compares the mass gained by growing rats consuming a diet containing a test protein compared to a diet containing casein as the reference protein.

> ***Protein quality is the ability of a protein source to meet the essential amino acid requirements of the animal.***

The pet food industry has also use the chick growth assay with egg as the reference protein for assessing protein quality. While the PER method provides a measure of protein quality, it is limited in application to growing animals and is not directly applicable to adult animals. Furthermore, differences in the amino acid requirements of rats and chicks compared to dogs or cats are significant limitations associated with the PER method making it an incomplete representation of protein quality.4 Nevertheless, this method provides a general ranking of protein quality when comparing various sources.

The protein-digestibility-corrected amino acid score (PDCAAS) was developed as a refinement to the PER method. PDCAAS is calculated as the product of the lowest essential amino acid score and the true total tract protein digestibility.[4] It was the first method to use total tract protein digestibility as an indirect measure of essential amino acid bioavailability. Scores for the essential amino acids in a protein source are calculated as the ratio between the digestible amino acid content in the protein and the specific amino acid requirement of the animal. The amino acid with the lowest calculated score is considered the first limiting amino acid. By definition, the limiting amino acid is the essential amino acid present in a food or protein source in the lowest proportion relative to its requirement for the animal. The protein quality of a food or ingredient is directly related to its limiting amino acid(s) because inadequate availability of all essential amino acids will limit protein synthesis in the animal's tissues which can affect overall function and health.

The protein quality of a food or ingredient directly relates to its limiting amino acids. This affects the ability of the animal to synthesize protein for various body functions and health.

The PDCAAS method also has a number of limitations. The use of total tract protein digestibility can overestimate amino acid bioavailability. In addition, all PDCAAS values are truncated to 1.0 which underestimates the value of high-quality ingredients and impedes the ability to accurately compare protein quality among ingredients when seeking complementary protein sources.[4]

The digestible indispensable amino acid score (DIAAS) method improves upon PDCAAS by using true ileal amino acid digestibility coefficients rather than true total tract protein digestibility. For determining protein quality for humans, ileal-cannulated pigs are used as the model for determining true ileal amino acid digestibility. Another advantage of the DIAAS method is that values are not truncated so some protein ingredients can have values greater than 100. For many years, PDCAAS was the chosen method by the Food and Agriculture Organization of the United Nations (FAO) for quantifying and characterizing protein quality in human food.5 However, an FAO report published in 2013 was the first time the organization recommended the use of DIAAS to replace PDCAAS.[6]

THE DIAAS-LIKE METHOD TO DETERMINE

Because DIAAS is now considered the preferred method for assessing protein quality in humans, ADM commissioned a series of additional evaluations at the University of Illinois Urbana- Champaign that used a modified version of this method (DIAAS-like method) to determine the protein quality of the preceding alternative protein sources for dogs and cats.[2,3] The DIAAS-like score was calculated as: DIAAS (%) = (mg of digestible AA in 1g dietary protein / mg of same AA in 1g of reference protein) x 100. The precision-fed cecectomized rooster assay was used as the surrogate model for dogs and cats to determine standardized amino acid digestibility values. The reference protein was determined from the amount of each essential amino acid present in 1g of protein based on AAFCO canine and feline adult maintenance requirements. The cecectomized rooster assay uses roosters with ceca surgically removed to provide an animal model of digestion without the effects of bacterial fermentation. In other words, it provides a method for true ileal amino acid digestibility of ingredients and foods. The method has proven to be an accurate model for companion animal nutrition based on its correlation to results from ileal-cannulated dogs.[2] While the accuracy of using cecectomized roosters as a model in feline nutrition has not been determined, it is generally accepted that amino acid digestibility differences are negligible between dogs and cats when total tract digestibility is greater than 90%.[2]

ADM Versity dried yeast had a high quality DIAAS like score for all essential amino acids indicating it does not contain any limiting amino acids for adult dogs or cats.

ADIAAS-like score of 100% or above is considered a source of high-quality protein for dogs and cats, while scores less than 100% but greater than 50% represent moderate-quality proteins, and scores below 50% are low-quality proteins that are insufficient as a primary source for the respective amino acid.[3] For each ingredient, the amino acid with the lowest DIAAS-like score below 100 represents the first limiting amino acid. Ingredients with DIAAS-like scores over 100 for all essential amino acids do not have a limiting amino acid and are capable of meeting all the requirements of the animal.

The DIAAS-like scores for the alternative protein ingredients compared with AAFCO minimal requirement values for adult dogs and cats are shown in Tables 4 and 5, respectively. For the individual essential amino acids within an ingredient, yellow cells identify moderate quality scores between 50 -99 and red cells indicate a score less than 50.

For dogs, methionine was the first limiting amino acid in all the legume-based ingredients: pea protein, green lentils, black bean grits garbanzo beans, yellow peas, soy protein concentrate, soy flakes and soybean meal. Tryptophan was the second limiting amino acid in pea protein, green lentils, garbanzo beans and yellow peas, while threonine was second limiting in soy flakes. In contrast to the other legume-based sources, peanut flour had three limiting amino acids (lysine, methionine and threonine).

For the non-legume ingredients, potato protein was limited in tryptophan while corn gluten meal was limited in lysine followed by tryptophan. ADM Versity dried yeast had a high quality DIAAS-like score for all essential amino acids indicating it does not contain any limiting amino acids for adult dogs.

This research provides a deeper understanding of plant and yeast protein sources for formulating pet food.

Interestingly, DIAAS-like calculations for cats showed fewer limiting amino acids among the alternative protein sources compared to dogs. This is related to the fact that cats have lower requirements for essential amino acids relative to their total protein requirement than dogs. This suggests that, contrary to popular belief, plant-based protein sources can be well-utilized by cats to meet their essential amino acid requirements. There were no limiting amino acids in pea protein, potato protein, soy protein concentrate, soybean meal, yellow peas, black bean grits, navy bean powder, garbanzo beans, and Versity dried yeast when fed to adult cats. Lysine was the first-limiting amino acid in corn gluten meal and peanut flour. Corn gluten meal was also limited in arginine and tryptophan while peanut flour was limited in threonine. Threonine was the first limiting amino acid in soy flakes. Green lentils were limited in tryptophan and methionine.

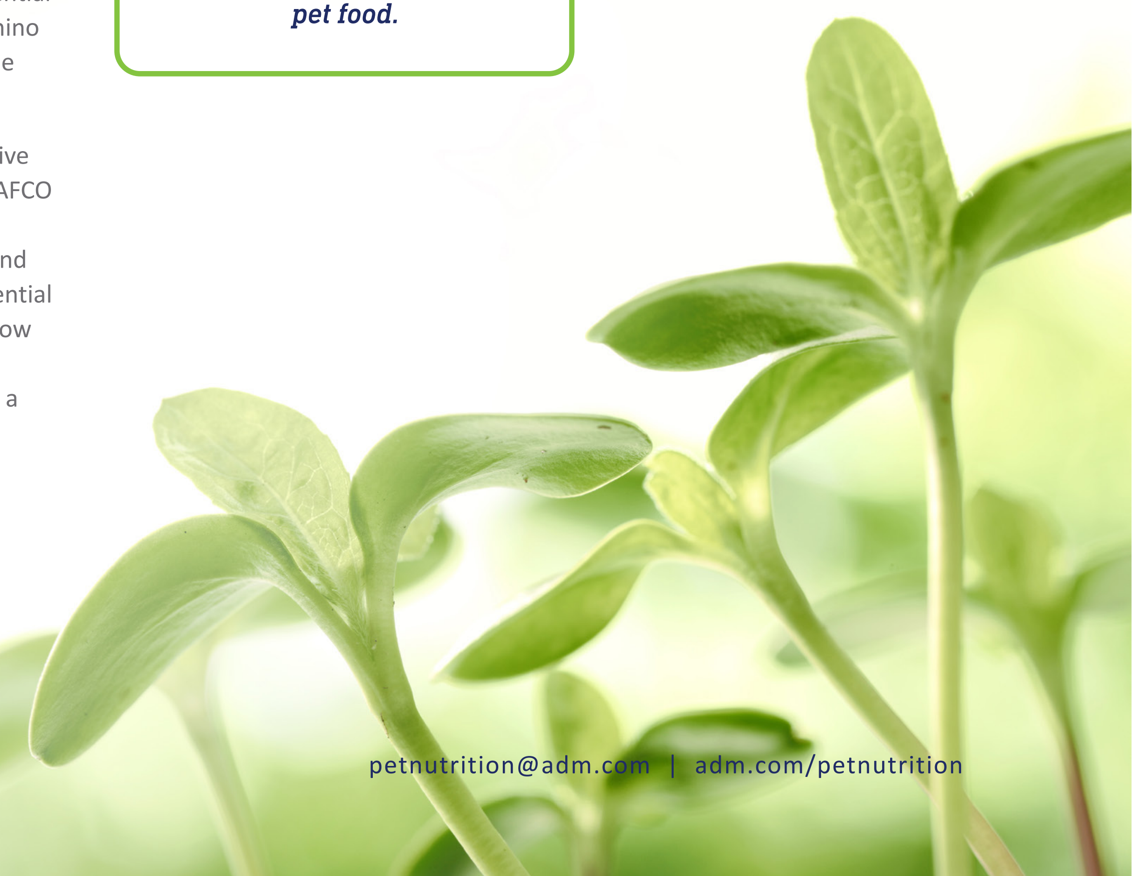

Table 4. DIAAS-like1 scores for plant-based and yeast protein sources compared with AAFCO minimum requirement values for adult dogs

Pulses	Arg	His	Lle	Leu	Lys	Met	Phe	Thr	Trp	Val
Yellow peas	270.2	210.9	193.8	174.5	202.4	44.5	178.6	129.9	74.6	169.3
Green lentils	238.6	179.4	181.1	158.9	168.4	30.5	170.7	109.1	36.4	152.7
Black bean grits	172.3	225.8	205.5	185.3	173.6	51.3	210.9	141.6	109.5	182.4
Navy bean powder	179.7	249.4	215.8	197.0	183.5	48.3	216.2	145.5	126.5	194.8
Garbanzo beans	340.6	216.1	186.8	166.7	165.2	64.8	209.8	111.3	84.9	148.4
Legume-based concentrates										
Pea protein	300.6	218.6	204.3	183.6	202.8	42.7	186.9	120.4	91.6	171.4
Soy protein concentrate	250.0	237.5	223.3	194.6	173.6	74.1	193.1	131.4	133.5	181.1
Soy flakes	216.1	195.1	177.1	152.9	140.7	54.6	160.3	97.9	128.1	139.1
Sobean meal	246.1	232.6	215.1	188.8	171.2	70.5	187.0	133.8	150.1	175.2
Peanut flour	320.5	172.0	141.7	145.2	25.1	44.5	180.0	67.5	116.9	135.1
Non-legume sources										
Gluten corn meal	114.5	186.7	195.3	421.3	43.1	135.5	243.3	112.4	67.5	167.9
Potato protein	171.7	198.7	268.5	262.6	214.9	118.6	248.7	198.3	97.5	249.9
Versity dried yeast	142.5	185.3	226.5	260.7	144.6	99.9	193.6	132.5	102.4	200.0

like (%) = [(mg of digestible indispensable amino acid in 1 g of dietary protein)/mg of same indispensable AA in 1 g of reference protein)] × 100.
Yellow cells indicate moderate quality DIAAS-like protein quality score (50- 99) and red cells indicate low quality DIAAS-like protein quality score (<50).

Table 5. DIAAS-like1 scores for plant-based and yeast protein sources compared with AAFCO minimum requirement values for adult cats

Pulses	Arg	His	Lle	Leu	Lys	Met	Phe	Thr	Trp	Val
Yellow peas	192.1	187.5	204.5	138.2	222.1	106.8	277.7	123.0	107.8	193.9
Green lentils	169.7	159.5	191.1	125.9	184.8	73.2	265.4	103.3	52.5	174.9
Black bean grits	122.5	200.8	216.9	146.8	190.5	123.1	327.9	134.1	158.2	209.0
Navy bean powder	127.8	221.8	227.7	156.1	201.4	115.7	336.2	137.8	182.8	223.3
Garbanzo beans	242.2	192.1	197.2	132.1	181.2	155.4	326.1	105.5	122.8	170.1
Legume-based concentrates										
Pea protein	213.7	194.3	215.7	145.5	222.5	102.4	290.7	114.0	132.4	196.4
Soy protein concentrate	177.8	211.2	235.7	154.1	190.5	177.6	300.2	124.5	192.9	207.5
Soy flakes	153.7	173.4	186.9	121.1	154.4	131.0	249.3	92.8	185.2	159.4
Sobean meal	174.9	206.8	227.0	149.6	187.9	168.9	290.8	126.7	217.0	200.8
Peanut flour	227.9	152.9	149.6	115.1	27.5	106.7	279.9	63.9	168.9	154.8
Non-legume sources										
Gluten corn meal	81.4	165.9	206.1	333.8	47.3	325.0	378.2	106.5	97.6	192.4
Potato protein	122.1	176.7	283.4	208.0	235.8	284.3	386.7	187.9	140.9	286.5
Versity dried yeast	101.3	164.8	239.1	206.5	158.7	239.8	300.9	125.6	148.0	229.2

1DIAAS-like (%) = [(mg of digestible indispensable amino acid in 1 g of dietary protein)/mg of same indispensable AA in 1 g of reference protein)] × 100.
Yellow cells indicate moderate quality DIAAS-like protein quality score (50- 99) and red cells indicate low quality DIAAS-like protein quality score (<50).

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This research provides much needed information for pet food ingredient suppliers, manufacturers and formulators on the nutrient composition and biological availability of alternative plant and yeast protein sources used in the industry. While some of the protein sources contain limiting amino acids, these protein sources are appropriate for use in canine and feline foods when used with complementary ingredients. Protein quality is not a fixed property of an ingredient because it can be affected by factors such as the overall food matrix, processing conditions, and physiological factors of the animal. Therefore, it is important to understand the nutritional composition of ingredients and how they interact with other ingredients to impact their digestibility and nutrient bioavailability in finished products. Thus, it is contingent upon pet food formulators and manufacturers to determine the most appropriate protein sources to include in a formulation based on the nutritional purpose and marketing goals of the formulation. The results of this research provide a deeper understanding of plant and yeast protein sources to assist in meeting formulation and product goals. At ADM we strive to provide solutions to the pet food industry and as such, we will continue to conduct research that supports the industry and ensures the health and well-being of dogs and cats.

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