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Calf Note #239 – Amino acids for calves, Part 2 – Amino acids in CMR

Introduction

In Calf Note #238, I discussed the complexity of predicting amino acid (**AA**) supply in young calves, particularly during the period (usually around weaning) when calves transition from monogastric digestion to ruminant fermentation and digestion. This transition period causes changes in the source of amino acids – i.e., early in life amino acids come exclusively from milk protein, but by a few weeks after weaning, the calf's amino acid supply is provided by a mix of undegraded dietary and microbial protein flowing from the rumen. This Calf Note will review AA composition of ingredients that make up CMR and the AA composition of whole milk.

Milk Amino Acids

Whole milk is often considered an "optimal" nutrient source for calves, with an excellent AA profile that meets the AA needs for maintenance and growth. Indeed, many manufacturers of calf milk replacers (**CMR**) use the milk AA profile as their template for AA.

Amino acids in CMR Ingredients

Using a simple review of published literature – peer reviewed and non-peer reviewed, I compiled some examples of reported AA profiles in several ingredients used in CMR formulas around the world. Tables 1 to 5 include milk, whey, soy, pea, and wheat protein AA profiles, respectively. The values are expressed as grams of AA per 100 grams of CP to account for differences in processing of various ingredients – for example, soy flour and soy protein concentrate have different absolute AA profiles, but when expressed as a percent of CP, the values are similar and reflect the AA profile of the protein.

The differences among protein sources in AA is shown clearly in Figure 1. The average concentration of each essential AA (**EAA**) in the CMR protein ingredients from Tables 1 to 5 are shown. Deficiencies of many EAA, but particularly lysine and methionine, are important. For example, the lysine content of wheat is 2% of the protein, while milk and whey are 8-9% of the CP. When formulating a CMR, most manufacturers will supplement lysine and methionine when using vegetable protein sources. We'll look at some CMR formulations and targets for AA in CMR in a future Calf Note.

Generally, the AA and EAA profiles of ingredients used in CMR will be consistent, though there are variations. For example, Magan et al. (2019) reported that the type of diet cows consumed affected the AA profile of the milk produced. And, of course, the methods used in processing ingredients have a profound effect on their digestibility. Ingredients that are exposed to high heat or have some degree of burning (scorch) during the drying process will be less digestible than high quality ingredients. Thus, finding a consistent source of high quality ingredients is essential. I briefly discussed some aspects of CMR quality in Calf Note #33.

Besides the AA profile, some vegetable ingredients such as soy flour contain other constituents that interfere with digestion or may cause allergic reactions in the animal. These constituents must be removed by additional processing prior to use in a CMR formula. These constituents are usually removed when the ingredients – like soy protein concentrate – are >75% CP. Highly processed ingredients like hydrolyzed wheat gluten are highly digestible and contain no antinutritional factors that limit their use in CMR.

Here's an example of how we might calculate the amino acid supply from milk or CMR:

- 6 L of whole milk × 3.4% CP × 7.9% of CP as lysine = 16 grams of lysine per day.
- 6 L of CMR at 12.5% solids, containing all whey ingredients and 20% CP = 6,000 × 12.5% solids × 21.1% CP (dry basis) × 8.8% of CP as lysine = 14 grams of lysine per day.

While this difference is only 2 grams per day, it could be important, as the CMR fed provides 14 / 16 = 87.5% of the lysine in whole milk.

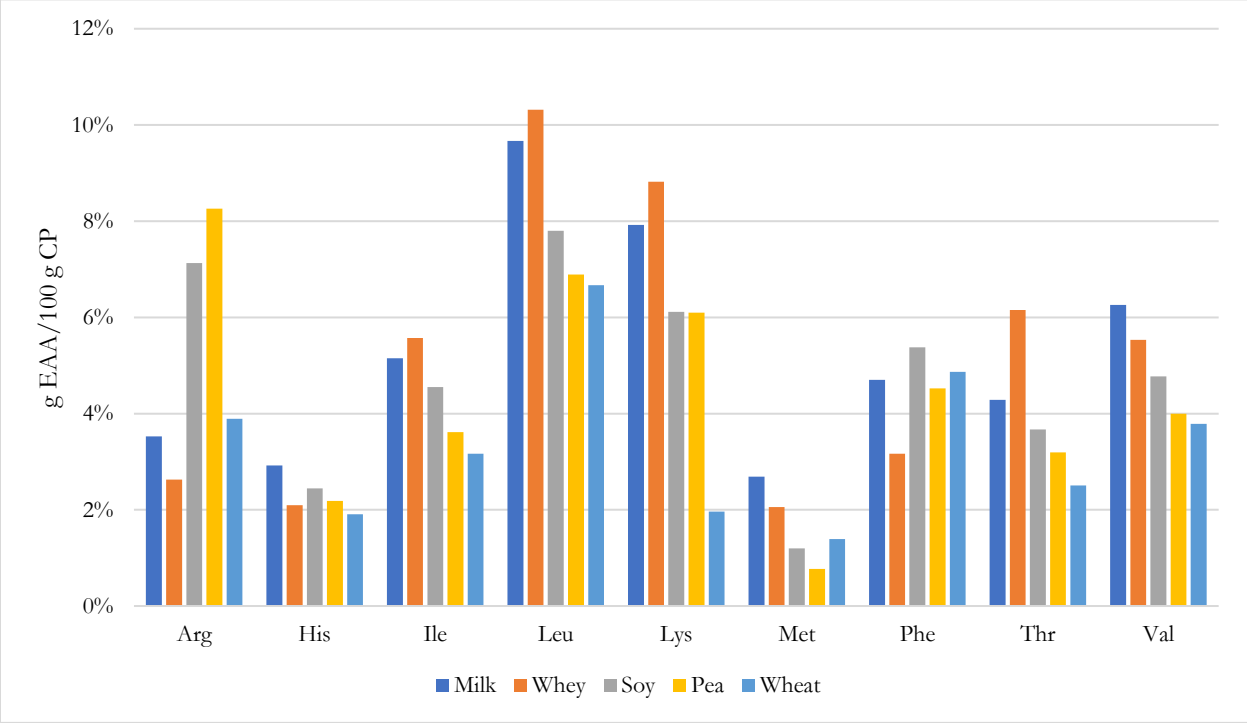

Figure 1. Essential amino acid (EAA) profile of selected ingredients used in CMR formulas.

Written by Dr. Jim Quigley (02 January 2023)

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Table 1. Essential amino acid composition (g/100 g CP) of milk proteins[1] from selected literature references.

Item	Milk	Milk	Milk	Milk	Milk	Milk	SMP	Milk	Milk	Milk	Milk	Milk	Milk	Milk	Milk	SMP Grass	SMP Clover	SMP TMR	MPC	Avg.	SD
Reference	21	5	4	3	13	20	12	17	17	17	17	17	17	17	17	11	11	11	12		
CP	35.0%	37.0%	27.2%	36.0%	35.8%	35.5%	34.7%	35.1%	34.5%	35.6%	35.6%	36.3%	35.7%	37.0%	36.9%	37.2%	37.5%	36.1%	67.9%	39.40%	
Arginine	3.7%	3.3%	3.3%	3.7%		3.6%	3.5%	4.0%	4.0%	3.8%	3.8%	3.7%	3.7%	3.8%	3.8%	3.1%	3.2%	3.2%	2.5%	3.53%	0.36%
Histidine	2.8%	2.4%	2.8%	2.8%	2.9%	2.7%	3.1%	2.9%	2.9%	2.9%	2.9%	3.0%	2.9%	2.9%	2.9%	3.6%	3.5%	3.6%	2.0%	2.92%	0.35%
Isoleucine	6.3%	3.7%	5.8%	5.4%	6.2%	6.1%	5.2%	5.4%	5.4%	4.9%	5.1%	5.1%	5.1%	5.6%	5.6%	4.4%	4.6%	4.5%	3.6%	5.15%	0.71%
Leucine	10.1%	9.0%	9.5%	9.4%	9.5%	9.8%	10.0%	10.2%	10.2%	10.1%	10.1%	10.2%	10.2%	10.1%	10.1%	9.4%	9.6%	9.5%	6.9%	9.67%	0.73%
Lysine	8.2%	7.6%	8.3%	7.9%	7.6%	8.0%	8.4%	8.5%	8.5%	8.4%	8.4%	8.5%	8.2%	8.5%	8.4%	7.3%	7.3%	7.4%	5.5%	7.92%	0.69%
Methionine	2.6%	2.7%	2.7%	2.8%	2.4%	2.5%	2.4%	2.8%	2.7%	2.6%	2.7%	2.5%	2.4%	2.7%	2.7%	3.3%	3.4%	3.5%	1.8%	2.69%	0.37%
Phenylalanine	5.0%	4.5%	4.3%	4.8%	4.6%	4.8%	4.9%	5.0%	5.0%	5.0%	5.0%	5.1%	5.2%	5.1%	5.1%	4.2%	4.2%	4.1%	3.4%	4.70%	0.44%
Threonine	4.7%	4.5%	3.9%	4.4%	4.3%	4.5%	4.3%	4.4%	4.4%	4.3%	4.3%	4.4%	4.5%	4.7%	4.6%	4.1%	4.1%	4.1%	3.0%	4.28%	0.34%
Valine	6.9%	4.6%	6.5%	6.2%	6.5%	6.7%	6.6%	6.8%	6.7%	6.6%	6.6%	6.8%	6.7%	6.8%	6.8%	5.5%	5.8%	5.6%	4.4%	6.26%	0.70%

[1]Milk = whole or skim milk; SMP = skim milk powder, MPC = milk protein concentrate.

Table 2. Essential amino acid composition (g/100 g CP) of whey proteins[1] from selected literature references.

Item	WPC	WPC	WPC	WPC	WPC	WPC	WPC	12% Whey	12% whey	Whey Grass	Whey Clover	Whey TMR	WPI	WPI	Avg	SD
Author	5	1	18	14	7	8	12	14	20	11	11	11	16	12		
CP	80.0%	75.0%	80.0%	53.0%	83.4%	71.0%	78.0%	11.0%	12.9%	9.3%	9.4%	9.6%	89.9%	85.2%	53.41%	
Arginine	2.1%	3.1%	2.9%	3.2%	2.9%	4.4%	2.4%	2.6%	2.9%	2.0%	2.0%	2.0%	2.4%	2.0%	2.63%	0.65%
Histidine	1.8%	2.1%	2.0%	2.2%	1.8%	2.1%	1.7%	2.2%	1.9%	2.5%	2.8%	2.6%	2.0%	1.7%	2.10%	0.33%
Isoleucine	4.8%	6.1%	6.2%	5.8%	6.2%	5.4%	4.9%	5.5%	5.6%	5.4%	5.2%	4.8%	6.2%	6.0%	5.57%	0.50%
Leucine	10.9%	11.7%	11.8%	12.3%	10.1%	10.4%	9.3%	12.0%	9.2%	8.8%	8.8%	8.2%	10.9%	9.9%	10.31%	1.29%
Lysine	9.0%	10.0%	10.1%	10.3%	9.4%	8.9%	7.8%	10.2%	8.0%	7.6%	7.5%	7.1%	9.1%	8.6%	8.82%	1.06%
Methionine	2.3%	2.1%	2.1%	2.1%	2.2%	2.1%	1.8%	2.1%	1.9%	2.1%	2.1%	2.0%	2.0%	1.9%	2.06%	0.13%
Phenylalanine	3.2%	3.5%	3.9%	3.8%	3.1%	3.8%	2.9%	3.8%	3.2%	2.4%	2.3%	2.3%	3.3%	2.9%	3.17%	0.55%
Threonine	6.8%	6.0%	7.5%	5.8%	6.8%	6.6%	5.4%	3.8%	6.4%	6.2%	6.0%	5.8%	6.4%	6.6%	6.15%	0.83%
Valine	4.4%	5.9%	6.4%	6.1%	5.4%	5.6%	4.8%	6.1%	5.4%	5.5%	5.3%	5.2%	6.0%	5.3%	5.53%	0.52%

[1]WPC = whey protein concentrate; WPI = whey protein isolate.

Table 3. Essential amino acid composition (g/100 g CP) of soybean proteins[1] used in calf milk replacers from selected literature references.

Item	SPC	SPI	SPC	SPC	SPC	SPC	SPI	Soy flour	Soy flour	Soy flour	Soy flour	Avg	SD
Reference	5	16	10	6	2	3	12	9	2	12	15		
CP	74.0%	91.6%	69.4%	81.8%	67.0%	84.4%	92.7%	45.0%	49.0%	52.3%	53.4%		
Arginine	6.5%	7.5%	7.4%	7.2%	7.1%	7.3%	7.0%		7.4%	7.1%	7.0%	7.1%	0.3%
Histidine	2.0%	2.5%	2.5%	2.8%	2.5%	2.6%	2.4%	2.2%	2.5%	2.7%	2.3%	2.4%	0.2%
Isoleucine	2.6%	4.8%	4.6%	4.9%	4.1%	4.5%	4.4%	6.9%	4.5%	4.5%	4.3%	4.6%	0.9%
Leucine	6.8%	8.0%	8.1%	7.6%	7.9%	7.8%	7.4%	9.1%	8.0%	7.6%	7.6%	7.8%	0.5%
Lysine	4.6%	6.3%	6.7%	6.4%	6.4%	6.2%	5.7%	6.4%	6.3%	6.3%	6.0%	6.1%	0.5%
Methionine	0.4%	1.3%	0.9%	1.5%	2.0%	1.4%	1.2%	0.4%	1.4%	1.4%	1.3%	1.2%	0.4%
Phenylalanine	4.3%	5.2%	5.3%	5.3%	5.3%	5.0%	4.9%	8.9%	5.3%	5.0%	4.8%	5.4%	1.1%
Threonine	3.1%	3.8%	4.1%	4.2%	3.9%	3.5%	3.4%	2.9%	4.0%	3.8%	3.8%	3.7%	0.4%
Valine	3.0%	4.7%	4.7%	5.2%	4.6%	4.8%	4.4%	6.7%	5.0%	4.8%	4.6%	4.8%	0.8%

[1]SPC = soy protein concentrate; SPI = soy protein isolate.

Table 4. Essential amino acid composition (g/100 g CP) of pea proteins[1] used in calf milk replacers from selected literature references.

Item	Pea	Pea	Pea	Pea	Pea	Avg	SD
Reference	5	19	1	3	12		
CP	80.0%	80.0%	76.5%	83.7%	54.5%	74.9%	10.5%
Arginine	7.4%	8.7%	8.7%	11.7%	4.8%	8.3%	2.2%
Histidine	2.0%	2.5%	2.5%	2.5%	1.4%	2.2%	0.4%
Isoleucine	2.9%	4.7%	4.5%	3.7%	2.3%	3.6%	0.9%
Leucine	7.1%	8.2%	8.4%	6.7%	4.0%	6.9%	1.6%
Lysine	5.9%	7.1%	7.2%	6.2%	4.1%	6.1%	1.1%
Methionine	0.4%	1.1%	1.1%	0.8%	0.5%	0.8%	0.3%
Phenylalanine	4.6%	5.5%	5.5%	4.3%	2.7%	4.5%	1.0%
Threonine	3.1%	3.8%	3.9%	3.2%	2.0%	3.2%	0.7%
Valine	3.4%	5.0%	5.0%	4.0%	2.6%	4.0%	0.9%

Table 5. Essential amino acid composition (g/100 g CP) of wheat gluten proteins[1] used in calf milk replacers from selected literature references.

Item	Wheat gluten	Wheat gluten	Wheat gluten	Wheat gluten	Avg	SD
Reference	3	1	5	16		
CP	85.0%	83.7%	81.0%	83.4%	83.3%	1.4%
Arginine	4.3%	3.6%	3.0%	4.7%	3.9%	0.7%
Histidine	2.1%	2.0%	1.7%	1.8%	1.9%	0.1%
Isoleucine	3.7%	3.5%	2.5%	3.0%	3.2%	0.5%
Leucine	6.7%	7.0%	6.2%	6.8%	6.7%	0.3%
Lysine	1.9%	1.8%	1.4%	2.8%	2.0%	0.5%
Methionine	1.4%	1.4%	0.9%	1.9%	1.4%	0.4%
Phenylalanine	5.3%	5.2%	4.6%	4.4%	4.9%	0.4%
Threonine	2.7%	2.5%	2.2%	2.6%	2.5%	0.2%
Valine	4.0%	3.8%	2.8%	4.5%	3.8%	0.6%