Role of isoleucine as a member of branched chain amino acids in poultry

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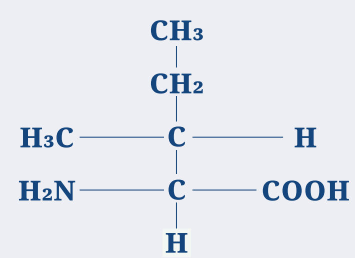
INTRODUCTION

In the present scenario of rising concern over the environmental issues, to reduce the nitrogen emission and to minimize the feed cost in the feed industry, lowering crude protein level with the addition of synthetic amino acids is the standard practice. In practical ration formulation a deficit of first-limiting amino acids can be prevented by supplying these amino acids in their free form particularly methionine, lysine, threonine, valine, arginine, and isoleucine (Ile). A progressive reduction of the dietary protein content can, however, lead to a situation where other amino acids, which are of no special concern in diets with normal protein levels, become limiting for performance. Isoleucine is considered as the fifth limiting amino acid in corn-soybean based diets and also can be a co-limiting amino acid together with valine in broilers diets when animal by products comprises 3% or more in the diet (Corzo et al., 2010).



Isoleucine

Isoleucine metabolism

Isoleucine is a branched chain amino acid (BCAA) and along with valine and leucine are essential amino acids. Although most of amino acids are catabolized in the liver, BCAAs are initially catabolized in skeletal muscle into BCKA (branched chain keto acid) with the involvement of branched-chain aminotransferase (BCAT) (leucine to α-keto isocaproate, valine to α-keto isovalerate, and isoleucine to α-keto-β-methyl-valerate). BCKA will be decarboxylated by branched-chain α-ketoacid dehydrogenase (BCKD) in the liver. Finally, these BCAA metabolites are catabolized by a series of enzymatic reactions to final-products (acetyl-CoA from leucine, succinyl-CoA from valine, and both acetyl-CoA and succinyl-CoA from isoleucine), which enter the TCA cycle (Fig. 1).

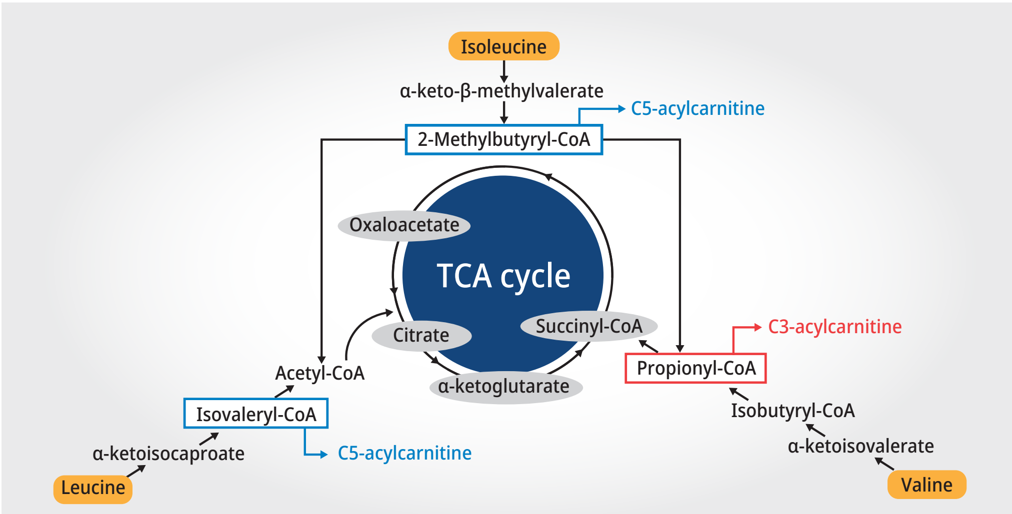


Figure 1. Pathway of branched chain amino acid catabolism.
(Adopted from Zhang et al., 2017)

Isoleucine requirement

The ideal ratio of Ile to Lys (dIle:dLys) for optimum growth performance and breast meat yield in broilers is considered as 67 (Kidd et al., 2004). According to a study by CJ Brazil (article in press) recommended SID Leu, Val, and Ile levels for optimal BW gain were estimated at 1.33, 0.96 and 0.84% for the starter phase; 1.23, 0.83 and 0.75% for the grower phase; and 1.16, 0.77 and 0.68% for the finisher phase, respectively. Similarly, SID Leu, Val, and Ile levels required for gain:feed optimization were estimated at 1.37, 0.94 and 0.87% during the starter phase; 1.23, 0.82 and 0.75% during the grower phase; and 1.15, 0.77 and 0.70% during the finisher phase, respectively. The NRC has increased its Ile recommendation for commercial layers to 650 mg/d per hen (NRC, 1994) from 550 mg/d per hen (NRC, 1984). For brown egg layers, NRC (1994) has recommended 715 mg isoleucine daily on 110 g of feed per hen. Harms and Russell (2000) suggested a daily requirement of Ile at 601 mg/d for a daily egg mass of 53g. The recommended dietary intake of dIle is 79% of lysine for single- comb white leghorn laying hens as per CVB (1996) (Table 2). The Ile requirements of turkeys and ducks are mentioned in Table 3.

Table 1. Ideal digestible amino acid profiles for broiler chickens expressed as percentage of lysine

Source	Cobb (2018)				Ross (2019)		
Age (Days)	0-8	9-18	19-28	>29	0-10	11-24	>25
Ile	*63*	*64*	*65*	*66*	*67*	*68*	*69*
Lys	100	100	100	100	100	100	100
Met	38	40	41	41	40	41	42
Met+Cys	75	76	78	78	74	76	78
Thr	68	65	65	65	67	67	67
Val	73	75	75	75	75	76	76
Arg	105	105	105	105	107	107	107
Leu	-	-	-	-	110	110	110
Trp	16	16	18	18	16	16	16

Table 2. Ideal amino acid profiles for single-comb white leghorn laying hens[1]

Amino acid	NRC (1994)[2]	CVB (1996)[3]	Coon and Zhang (1999)[4]	Lesson and Summer (2005)[5]	Rostagno (2005)[6]	Bregendahl et al. (2008)[7]
Ile	*94*	*79*	*86*	*79*	*83*	*79*
Lys	100	100	100	100	100	100
Arg	101	-	130	103	100	-[8]
Met	43	50	49	51	50	47
Met +Cys	84	93	81	88	91	94
Thr	68	66	73	80	66	77
Trp	23	19	20	21	23	22
Val	101	86	102	89	90	93

[1]Amino acid requirements expressed as a percentage of the requirement or recommendation for lysine.
[2]Calculated from total amino acid requirements.
[3]Calculated from digestible amino acid recommendations.
[4]Based on digestible amino acid requirements.
[5]Calculated from total amino acid recommendations for 32-to-45-week-old laying hens.
[6]Digestible amino acid basis.
[7]Based on true digestible amino acid requirements for maximal egg mass in 28-to-34-week-old laying hens.
[8]The arginine:lysine ratio was estimated to be 107 or less.

Table 3. Isoleucine requirement of Turkeys and White Pekin Ducks (%) (90% DM) NRC (1994)

Growing Turkeys (Males)							Breeders	Laying hens
Weeks	0-4	4-8	8-12	12-16	16-20	20-24		
Ile	*1.1*	*1.0*	*0.8*	*0.6*	*0.5*	*0.45*	*0.4*	*0.5*
White Pekin Ducks							Breeders	
Weeks	0-2			2-7				
Ile	*0.63*			*0.46*			*0.38*	

Isoleucine content in raw materials

The approximate isoleucine (%) in the common feed ingredients is given in Table 4.

Table 4. Isoleucine content (%) of commonly used feed ingredients

Ingredients (As fed basis)	Isoleucine %	
	Total %	Digestible %
Barley	0.42	0.34
Canola meal (38%)	1.51	1.25
Corn	0.29	0.26
Corn gluten meal	2.30	2.19
Cotton seed meal, mech extracted	1.31	0.93
Cotton seed meal, direct solv.	1.33	0.95
Fish meal, white	3.00	2.55
Flax seed	0.95	0.81
Linseed meal flax, expeller	1.70	1.49
Linseed meal flax, solvent	1.80	1.58
Meat bone meal	1.70	1.41
Millet, pearl grain	0.52	0.46
Oats grain	0.53	0.47
Poultry by product meal	2.10	1.79
Rice bran, unextracted	0.39	0.30
Rice grain rough	0.33	0.27
Safflower seed meal, expeller	0.28	0.22
Sorghum, milo, grain	0.60	0.53
Soybean meal, expeller	2.18	1.94
Soybean meal, solvent	2.50	2.22
Sunflower meal, expeller	2.40	2.14
Sunflower meal, solvent	1.39	1.25
Wheat, hard grain	0.69	0.61
Wheat, soft grain	0.43	0.38
Wheat bran	0.60	0.47
Wheat middlings	0.70	0.58

Amino acid digestibility expressed as standardized ileal digestibility. Amino acid values are standardized for 88% dry matter (Source: Hy- Line. W-36 commercial layer management guide).

Beyond performance roles of isoleucine

Immunity

Immune cells oxidize BCAA as fuel sources and incorporate BCAA as the precursors for the synthesis of new immune cells, effector molecules, and protective molecules. Lack of BCAA in diet impairs many aspects of immune function and increases susceptibility to pathogens (Zhang et al., 2017).

Isoleucine and leucine contribute to immunity through the mammalian target of rapamycin (mTOR) signalling pathway. mTOR plays a vital role in the regulation of innate and adaptive immune responses and also various immune functions like promoting differentiation, activation and function in T-cells, B-cells and antigen presenting cells (Soliman, 2013). Isoleucine level also have a strong correlation with the excretion of β-defensin. Deficiencies of BCAA (leucine, isoleucine, valine) cause involution of the thymus (Konashi et al., 2000). Isoleucine could become marginal and its limitation could impair the immune function responses when hens are fed low protein diets (Konashi et al., 2000).

Feed consumption

The mTOR signalling pathway plays a vital role in the brain to detect nutrient availability and regulate energy balance (Cota et al., 2006). As isoleucine is also associated with mTOR signalling thus, low level of isoleucine can cause reduced feed intake.

BCAA deficient diet dramatically reduces feed intake by activating the GCN2 signalling pathway, which might participate in lipolysis (down-regulating lipogenesis genes or up-regulating lipolysis genes) in the liver and adipose tissue.

Glucose transportation

The function of isoleucine in enhancing glucose uptake and muscular glucose transporter expression (GLUT1 and GLUT4) was also demonstrated in C2C12 myotubes (Zhang et al., 2017). GLUT1 and GLUT4 are vital glucose transporters in muscle. Similarly, SGLT1 and GLUT2 are important glucose transporters in the small intestine. Isoleucine could potentially increase muscle growth and intestinal development and health by up-regulating the protein expression of GLUT1 and GLUT4 in muscle and enhancing the expression of SGLT1 and GLUT2 in the small intestine (Fig. 2).

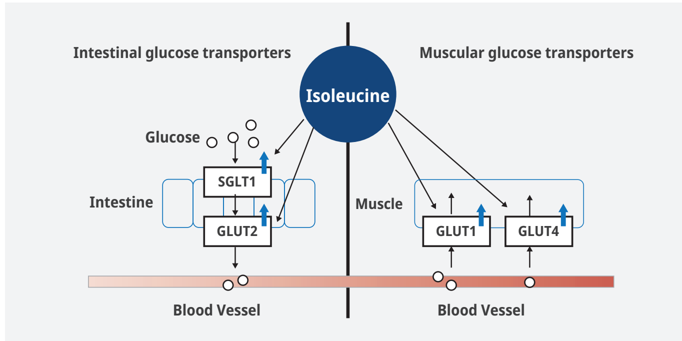


Figure 2. Isoleucine up-regulates intestinal and muscular transporters.
(Adopted from Zhang et al., 2017)

CONCLUSION

Lowering the crude protein level in poultry diet is a trend in poultry industry to address the current environmental pollution and for optimization of feed cost and isoleucine plays vital role in maintaining the amino acid balance in a low crude protein diet. Again, isoleucine along with valine and leucine also have positive influence on nutrient metabolism as well as immunity and gut health which can be focused further to have a clear impression.

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