Introduction

Milk is the exclusive nutrient source for the neonate. Enhanced management practices and availability of highly selected sows have allowed for increased litter sizes. The ability of the sow to produce adequate milk for large litters is limiting to neonate growth and total pig production (Boyd & Kensinger, 1998). Many studies have focused on improving nutrition for the high-producing lactating sow to maximize sow productivity.

Free amino acids in the blood are taken up by the lactating mammary gland. Once inside the mammary epithelial cell, the amino acids undergo various intracellular metabolic fates. The rate of protein synthesis is dependent upon three potential limiting steps: the amount of free amino acid available in the bloodstream, the ability of the transporter to take up the amino acid, and the various pathways the amino acid may enter once inside the cell.

Nutrition studies have shown that adding supplemental dietary lysine increases lactational performance of sows with large litters (Knabe et al. 1996). Supplemental lysine may affect the balance of plasma amino acids and alter mammary uptake of other amino acids, including valine (Knabe et al. 1996; Richert et al. 1996). Our previous studies have demonstrated that various amino acids, including branched chain amino acids (BCAA), can inhibit lysine uptake in sow mammary tissue (Schmid et al., 1999 Illinois Swine Research Report). Valine and lysine interactions can have physiological effects when supplemented in the sow diet. Nutrition studies also have found that supplemental dietary valine might increase litter weight gain (Richert et al. 1996; Tokach et al. 1993).

Valine and other BCAA are taken up by the mammary gland in quantities higher than their output in milk (Linzell et al. 1969, Trottier et al. 1997). Intracellular metabolic pathways other than protein synthesis may account for a significant portion of the BCAA taken up by the gland (Hurley & Bryson, 1997 Illinois Swine Research Report). Alternative fates of BCAA in the mammary gland, depending upon the amino acid, may include synthesis of cellular protein, synthesis of nonessential amino acids, utilization in fatty acid synthesis, and oxidization as an energy source. Animal nutrition studies do not usually account for these alternate metabolic pathways in the mammary gland.

Studies in the lactating mammary gland of other species have shown valine to be taken up via the system L transporter. Identified in mouse, rat, guinea pig, and cow, this transporter is generally specific for uptake of BCAA (Shennan 1998). However, the system L transporter will also take up each of the neutral amino acids. The low specificity of the L transporter may mean that the balance of amino acids in the blood is particularly crucial to the transport of valine.

Valine uptake and intracellular metabolism is not well understood for the lactating sow at the mammary gland level. The objective of this study was to characterize ion dependency, kinetics, and specificity of the valine uptake system in the lactating sow mammary gland.

Experimental Approach

Lactating sows (day 15 of lactation or later) from the University of Illinois swine herd were slaughtered at the University of Illinois Meat Science Laboratory abattoir. Litters were removed immediately prior to slaughter. Mammary tissue was cut into
fragments and incubated in the presence of media which demonstrated sodium dependency of valine uptake (culture media containing low vs physiological sodium concentrations), valine uptake kinetics (culture media containing valine concentrations ranging from 5 micromolar to over 5 millimolar), and competition by other amino acids (culture medium containing a low concentration of valine and supraphysiological concentrations of competitors).

**Results**

Uptake of valine increased with increasing medium concentration of valine. The kinetic analysis of valine uptake indicates that, within the range of physiological concentrations, the affinity of the valine uptake system is not limiting to valine uptake. Saturation of the valine transporter would not be expected to be a limiting factor when considering manipulation of blood valine levels.

System L has been characterized in the rat and cow as sodium independent (Shennan 1998; Baumrucker 1985). However in lactating sow mammary tissue, valine uptake was sodium dependent. This observation points out the variation in uptake mechanisms which exist among species.

Competition of valine uptake by high concentrations of leucine showed strong inhibition of valine uptake (Table 1). Even at physiological concentrations of leucine (320µM) valine uptake was inhibited by 47%. This is consistent with the specificity of the sow mammary tissue valine uptake system for BCAA.

Further competition experiments tested high concentrations of competitor amino acids. Several other amino acids showed inhibitory effects on valine (Table 1). Valine was inhibited by alanine (a short chain neutral amino acid), methionine (a sulfur containing short chain amino acid), glutamine (an amide derivative of an acidic amino acid), cyclo-leucine (a non-protein amino acid typically taken up by system L), and lysine (a cationic amino acid). The high concentrations of competitor amino acids used in these experiments do not represent physiological competition, but the results do demonstrate that other amino acids besides the BCAA are potential competitors for valine uptake. Methyl aminoisobutyric acid (MeAIB) is a non-metabolizable substrate for system A, an uptake system that is principally responsible for the uptake of short-chain, neutral amino acids. Competition with MeAIB showed no significant inhibition even at supraphysiological concentrations, indicating that the valine transport system does have a level of specificity.

**Conclusions**

These studies have characterized fundamental kinetics and specificity of the valine transporter, and have added to our understanding of the nature and limitations of amino acid uptake mechanisms in porcine mammary tissue. An understanding of the valine uptake system is an important step in optimizing amino acid nutrition for lactating sows. Further studies are necessary to examine the intracellular metabolism of valine to understand its role in milk protein synthesis.

**Acknowledgments**

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Table 1. *Inhibition of valine uptake by lactating sow mammary tissue by other amino acids.*

<table>
<thead>
<tr>
<th>Amino Acid Competitor</th>
<th>% Inhibition$^2$</th>
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<tr>
<td>Leucine</td>
<td>90.67 ± 3.23</td>
</tr>
<tr>
<td>Alanine</td>
<td>88.83 ± 2.65</td>
</tr>
<tr>
<td>Lysine</td>
<td>67.22 ± 3.30</td>
</tr>
<tr>
<td>Cyclo-Leucine</td>
<td>80.72 ±3.08</td>
</tr>
<tr>
<td>Glutamine</td>
<td>85.31 ± 2.21</td>
</tr>
<tr>
<td>Methionine</td>
<td>90.75 ± 3.12</td>
</tr>
<tr>
<td>Methyl aminoisobutyric acid</td>
<td>18.28 ± 10.27</td>
</tr>
</tbody>
</table>

$^1$ Valine at 20 micromolar and competitors at 20.48 millimolar; n=6 sows
$^2$ Inhibition calculated as valine uptake in the presence of competitor as a percentage of uptake in the absence of competitor. Values are means ± standard error of the mean.

References


