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Original Article

Protein Insufficiency Among First-Trimester Pregnant Women in Jambi, Indonesia

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Abstract

Background: Insufficient protein intake or specific patterns of plasma amino acid levels during pregnancy has been associated with adverse maternal and neonatal outcomes. Studies in non-pregnant women have reported an association between protein intake and amino acid levels, however, data in pregnant women remain limited. Jambi, a region rich in freshwater fish, has a traditional dishes based on fish, which may affect maternal protein adequacy. This study aimed to assess protein sufficiency intake, plasma essential amino acid levels, and the relationship between fish consumption and protein intake among first-trimester pregnant women.

Methods: A cross-sectional study was conducted in 2022 involving pregnant women at 9–16 weeks of gestation in Jambi, Indonesia, selected through purposive sampling. Protein intake and fish consumption data were collected using Food Frequency Questionnaires. Plasma essential amino acid levels were measured using Liquid Chromatography-Mass Spectrometry. Bivariate analyses were performed using Mann-Whitney and Chi-square tests.

Results: Among 30 participants, 23.3% had insufficient protein intake and had lower plasma essential amino acid levels. Lysine levels showed a statistically significant difference between groups ($p=0.010$). Women with adequate protein intake reported significant higher fish consumption, particularly of freshwater fish ($p=0.033$).

Conclusion: Adequate protein intake during early pregnancy is related to higher plasma essential amino acid levels. Consumption of local freshwater fish contributes to maintaining sufficient protein intake. These findings emphasize the importance of integrating healthy dietary patterns and locally sourced nutrient-rich foods into prenatal care to support maternal wellness and long-term health outcomes.

Keywords: Essential amino acid, freshwater fish, pregnancy, protein intake, lysine

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Introduction

Pregnancy is a special stage in life, defined by profound maternal physiological changes to support rapid fetal growth and development. These changes require adequate protein intake to ensure optimal maternal and neonatal outcomes. Previous studies have reported that inadequate protein intake is associated with various pregnancy complications, including preeclampsia, gestational diabetes, and intrauterine growth restriction (IUGR).[1,2]

Dietary proteins are digested and absorbed in the gastrointestinal tract as amino acids. These amino acids are categorized into essential amino acids, which can only be obtained through dietary intake, and non-essential amino acids, which can be synthesized by the human body in addition to being derived from the dietary sources . Essential amino acids are vital throughout life, for energy production, protein synthesis, and the formation of non-essential amino acids. They also serve as precursors for hormones, neurotransmitters, and other specialized metabolites.[3]

During pregnancy, amino acids play a crucial role in activating the nutrient-sensing system, particularly the mammalian target of rapamycin (mTOR) signaling pathway. This pathway regulates gene expression, supports angiogenesis, and modulate inflammation and oxidative stress.[4] Longitudinal studies have shown that plasma amino acid levels differ between non-pregnant women compared to and pregnant women and fluctuate across the different trimesters. These variations reflect fetal growth requirements and changes in placental amino acid transport.[5,6]

Additionally, previous studies have identified distinct amino acid profiles in pregnancies complicated by disorders compared to normal pregnancies.[7,8] Elevated levels of glutamate, histidine, serine, tyrosine, and phenylalanine, along with reduced levels of arginine, citrulline, glycine, leucine, ornithine, and valine, have been observed in preeclampsia.[9,10] Similarly, increased levels of branched-chain amino acids (BCAAs), including leucine, isoleucine, and valine have been significantly associated with IUGR and increased insulin resistance.[11]

In non-pregnant populations, plasma essential amino acid levels have been shown to correlate positively with dietary protein intake. Furthermore, a study in pregnant animal models indicate that inadequate protein intake leads to reduced plasma essential amino acid concentrations and an elevated risk of IUGR. Variations in dietary preferences are associated with different plasma essential amino acid patterns.[8] However, research exploring this association in human pregnancy remains limited. To date, only one study conducted in China has investigated the relationship between dietary intake and plasma amino acid levels during pregnancy. This study found that protein intake from dairy products and refined grains positively correlated with maternal sulfur-containing amino acids, particularly cysteine.[12] However, the dietary patterns observed in that population may differ substantially from those in Jambi, Indonesia.

Jambi is a province abundant in fishery resources, including rivers, lakes, and coastal waters, which contribute to a high consumption of freshwater and marine fish.[13,14] Given that the local diet is predominantly fish-based, dietary patterns in this population may influence both protein adequacy and plasma essential amino acid profiles differently from other regions. Therefore, this study aimed to assess maternal protein sufficiency, plasma essential amino acid levels, and dietary protein intake based on fish consumption among first-trimester pregnant women in Jambi, Indonesia.

Methods

This cross-sectional study was conducted from August to November 2022 and involved pregnant women aged over 18 years with gestational ages between 9 and 16 weeks. Participants were recruited from three public health centers in Jambi, Indonesia, namely Tahtul Yaman, Pakuan Baru, and Talang Bakung. Pregnant women diagnosed with hyperemesis gravidarum or acute infections were excluded from the study. All participants provided written informed consent after receiving an explanation of the study objectives and procedures. The study protocol was approved by the Ethics Committee of the Faculty of Medicine and Health Sciences, Universitas Jambi (No. 2445/UN21.8/PT.01.04/2022).

Body Mass Index (BMI) was calculated using the standard formula of weight and classified followed the Asia-Pacific BMI standard, with underweight defined as a BMI of less than 18.5 kg/m^2, normal weight as a BMI between 18.5 and 25.0 kg/m^2, and obesity as a BMI greater than 25 kg/m^2.[15]

Nutritional intake was assessed using a validated Food Frequency Questionnaire (FFQ), which measured the frequency and amount of food consumed on a daily basis.[16] A trained nutritionist assisted participants in completing the FFQ using a food model to improve accuracy. Nutritional adequacy was evaluated based on the Indonesian Recommended Dietary Allowances (RDA). Fish intake was assessed according to the Food and Drug Administration (FDA) criteria, with weekly consumption classified as sufficient if intake was more than 224 grams per week and insufficient if intake was 224 grams per week or less. Frequency of fish consumption was categorized into two groups: more than twice per week and twice or fewer per week. Protein and macronutrient intake data were analyzed using the NutriSurvey software.[17]

Fasting blood samples were collected from the antecubital vein after an overnight fast of 10 hours. A volume of 5 mL of venous blood was drawn from each participant. Plasma was separated and analyzed to determine the concentrations of essential amino acids using Liquid Chromatography-Mass Spectrometry (LC-MS), following a previously established protocol.[18] The analysis measured the plasma levels of nine essential amino acids, namely threonine, histidine, lysine, arginine, methionine, valine, isoleucine, leucine, and phenylalanine. These concentrations were then compared to reference values based on the Mayo Clinic standards (Table 2). All laboratory analyses were conducted at Prodia Laboratory, a certified clinical laboratory.

Statistical analysis was conducted to describe the clinical characteristics, dietary intake, and plasma amino acid levels of participants. Continuous data were presented as means with standard deviations (SD) for normally distributed variables, while non-normally distributed variables were expressed as medians with minimum and maximum values. An unpaired t-test was used to compare means between groups when data were normally distributed, while the Mann-Whitney U test was applied for non-parametric data. Categorical variables were presented as frequencies and percentages, with comparisons made using the Chi-square test or the Fisher exact test when expected frequencies were low. A bivariate analysis was performed to assess the association between plasma essential amino acid levels and daily protein intake. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 30 pregnant women were included in this study, with a mean age of 28.87 years and an average gestational age of 12 weeks. The proportion of women with a normal BMI before pregnancy was 56.7%. Primiparous women accounted for 46.7% of the participants. Most participants had completed senior high school (46.6%), and the proportion of housewives was higher than that of employed women. Notably, none of the participants reported smoking or alcohol consumption during pregnancy. The proportion of women with sufficient protein intake was 76.7%, and sufficient fat intake was 93.3%, both higher than the proportion with insufficient intake. In contrast, the frequency of participants with insufficient carbohydrate intake was higher (70.0%) than those with sufficient intake, as depicted in Table 1.

Table 1 Baseline Characteristics of Pregnant Women at 9–16 Weeks of Gestation from Three Public Health Centers in Jambi, Indonesia (n=30)

Characteristic	n (%) or Mean ± SD
Age (years)	28.87±4.58)
Gestational age (weeks)	12.03±2.99
BMI classification	
Underweight (<18.5)	4 (13.3)
Normal (18.5–25.0)	17 (56.7)
Obese (>25)	9 (30.0)
Pregnancy, n (%)	
First pregnancy	5 (16.7)
Later pregnancy	25 (83.3)
Parity, n (%)	
Nulliparous	7 (23.3)
Primiparous	14 (46.7)
Multiparous	9 (30.0)
Smoking, n (%)	
Yes	-
No	30 (100)
Alcohol consumption, n %)	
Yes	-
No	30 (100)
Education level, n (%)	
Primary school	2 (6.7)
Elementary school	2 (6.7)
Senior high school	14 (46.6)
Higher education	12 (40.0)
Occupation, n (%)	
Working	11 (36.7)
Housewife	19 (63.3)
Protein intake, n (%)	
Indonesian RDA	
Insufficient	7 (23.3)
Sufficient	23 (76.7)
Fat intake, n (%)	
Indonesian RDA	
Insufficient	2 (6.7)
Sufficient	28 (93.3)
Carbohydrate intake, n (%)	
Indonesian RDA	
Insufficient	21 (70.0)
Sufficient	9 (30.0)

Note: BMI=body mass index; RDA=recommended dietary allowance

Table 2 Plasma Essential Amino Acids Level Based on Protein Intake Sufficiency

Amino acids (µmol/L)	Insufficient protein intake	Sufficient protein intake	P-value
	Median (min–max)	Median (min–max)	
Threonine	73.29 (59.86–87.25)	83.52 (78.66–87.91)	0.090
Histidine	55.00 (27.00–85.00)	65.00 (39.00–83.00)	0.492
Lysine	**105.14 (82.00–130.80)**	**141.26 (127.80–154.18)**	**0.010**
Arginine	69.00 (59.00–996.00)	96.00 (57.00–150.00)	0.641
Methionine	17.14 (14.60–20.14)	17.65 (15.38–19.83)	0.822
Valine	134.00 (109.63–157.62)	175.87 (154.40–200.83))	0.063
Isoleucine	55.00 (26.00–82.00)	40.00 (26.00–71.00)	0.364
Leucine	71.71 (32.00–112.00)	96.65 (80.42–115.63)	0.206
Phenylalanine	53.43 (45.56–63.50)	64.13 (59.14–69.20)	0.051

Note: A p-value of less than 0.05 was considered statistically significant

Table 3 Association Between Fish Intake and Protein Sufficiency

Amino acids (µmol/L)	Insufficient protein intake	Sufficient protein intake	P-value
Amount of fish intake (g/day)			
Freshwater fish	1.77 (0.00–265.00)	32.67 (0.00–850.00)	0.033
Marine fish	0.5 (0.00–50.00)	6.00 (0.00–425)	0.311
Total fish	3.33 (0.00–315.00)	37.83 (0.00–1275)	0.003
Subjects based on weekly intake			
≤ 224 g/week, n (%)	6 (20.0%)	9 (30.0%)	0.031
>224 g/week, n (%)	1 (3.3%)	14 (46.7%)	
Frequency of fish consumption			
≤ twice/week, n (%)	6 (20.0%)	9 (30.0%)	0.031
> twice/week, n (%)	1 (3.3%)	14 (46.7%)	

Note. Data are presented as median (minimum–maximum) for continuous variables and n (%) for categorical variables. Chi-square test was used for categorical data; non-parametric tests were used for continuous data due to non-normal distribution

Participants with sufficient protein intake had higher plasma levels of nearly all essential amino acids compared to those with insufficient intake, except for isoleucine. Interestingly, the plasma level of isoleucine was lower in the sufficient protein intake group (40.0 µmol/L) compared to the insufficient group (55.0 µmol/L). Furthermore, the proportion of participants with sufficient protein intake whose plasma essential amino acid levels were within the reference range was higher for all amino acids. However, a statistically significant difference was observed only for lysine (p=0.010), while differences in other amino acids were not statistically significant (Table 2).

This study also assessed dietary fish intake as a source of protein (Table 3). The amount of fish consumption was significantly higher in the sufficient protein intake group (p=0.003), particularly for freshwater fish (p=0.033). Based on FDA recommendations, the frequency of participants consuming more than 224 grams of fish per week or eating fish more than twice a week was also higher in the sufficient protein intake group.

Discussion

The main finding of this study is that 23.3% of pregnant women had insufficient protein intake during the first trimester. Plasma essential amino acid levels tended to be higher in those with sufficient protein intake, with a significant increase observed for lysine. Insufficient protein intake and lower plasma essential amino acid levels have been associated with adverse maternal and neonatal outcomes.[18,19] Essential amino acids must be obtained through dietary sources, as they cannot be synthesized by the human body. Furthermore, the type of dietary protein consumed influences the amino acid profile provided.[20] In addition to the quantity of protein, pregnant women should consider the diversity of protein sources to ensure nutritional adequacy.

This study also found that pregnant women who consumed freshwater fish frequently and in larger portions were more likely to have sufficient protein intake. This finding is consistent with a previous study, showing that moderate freshwater fish consumption during pregnancy was associated with a reduced risk of small for gestational age infants, , supporting the nutritional benefits of freshwater fish consumption during pregnancy.[21]

Pregnancy is a physiologically demanding period characterized by increased energy and nutrient requirements. In this study, a proportion of pregnant women exhibited not only insufficient protein intake but also a high frequency of inadequate carbohydrate intake relative to the Indonesian Recommended Dietary Allowances (RDA). Nutritional demands increase from the first trimester onwards. According to the Indonesian RDA, protein requirements increase by 1 gram per day during the first trimester, 10 grams during the second trimester, and 30 grams during the third trimester.[22,23] The primary role of protein in pregnancy extends beyond energy provision to serve as a critical substrate for protein synthesis and the production of bioactive compounds essential for maternal adaptations and fetal development. Previous studies have shown that inadequate protein intake is linked to adverse outcomes, including maternal insulin resistance, preeclampsia, preterm birth, and impaired fetal neurodevelopment.[1,4]

Carbohydrate needs also increase during pregnancy, with recommendations suggesting an additional 25 grams per day in the first trimester, rising to 40 grams in the second and third trimesters.[19,20,22] Carbohydrates serve as the primary energy source, comprising approximately 50–60% of total caloric intake. Insufficient carbohydrate intake can impair fetal growth and development.[22] The high prevalence of inadequate carbohydrate intake observed in this study may be attributed to common first-trimester symptoms such as nausea, vomiting, and reduced appetite, which limit overall food intake. This highlights the importance of monitoring maternal nutrition early in pregnancy to prevent adverse outcomes for both mother and child.

Dietary protein is metabolized into amino acids in the digestive tract. Since essential amino acids cannot be synthesized endogenously, plasma levels largely depend on dietary intake. In non-pregnant populations, dietary patterns are a primary determinant of plasma essential amino acid levels. During pregnancy, fetal growth progressively increases the demand for maternal amino acids. Studies have reported declining levels of certain amino acids, such as arginine, valine, and leucine, as gestational age advances, reflecting increased fetal demands and metabolic adaptations. These patterns suggest that plasma essential amino acid levels in early pregnancy are significantly influenced by dietary intake.[6,7,24]

In this study, pregnant women in their first trimester with adequate protein intake exhibited higher levels of essential amino acids, particularly lysine. This finding suggests the importance of early dietary intake in determining plasma amino acid profiles. Maintaining adequate essential amino acid levels is crucial supporting maternal physiological adaptations and optimal fetal development. Previous study has reported increased requirement for threonine, lysine, isoleucine, and tryptophan during early pregnancy.[3] These amino acids are essential for protein synthesis, hormone production, neurotransmitter synthesis, regulation of gene expression, activation of nutrient-sensing pathways such as mTOR, angiogenesis, and reduction of inflammation and oxidative stress.[3,4,25]

Each essential plasma amino acids play a specific role in pregnancy. Arginine supports nitric oxide synthesis, which is crucial for vasodilation and placental circulation, as well as for modulating oxidative stress and maternal-fetal immune tolerance. Degradation of maternal arginine by fetal arginase-2 further supports pregnancy maintenance. Leucine and valine, both branched-chain amino acids (BCAAs), serve as nitrogen donors for the synthesis of non-essential amino acids like alanine and glutamine, which become increasingly important as gestation progresses. Leucine also activates the mTOR pathway, promoting protein synthesis and preventing proteolysis, which is critical for fetal growth. Threonine levels tend to increase due to reduced oxidation during pregnancy.[4,6,7,24] Lysine is essential for collagen formation and serves as a precursor to carnitine.[18] Meanwhile, methionine, a precursor to S-adenosyl methionine, plays a key role in gene expression by regulating DNA methylation.[4]

Disruptions in amino acid profiles are associated with adverse pregnancy outcomes. Elevated levels of glutamate, histidine, and serine, alongside decreased levels of arginine and methionine, are characteristic of preeclampsia. Glutamate promotes inducible nitric oxide synthase (iNOS) production, contributing to oxidative stress in preeclamptic pregnancies. Additionally, elevated levels of serine and glycine have been linked to placental defects in preeclamptic patients. In contrast, several studies have reported decreased levels of arginine and methionine, which may be related to the role of methionine in protecting cells from oxidative damage. Arginine, a precursor for nitric oxide, is reduced in preeclampsia. Nitric oxide is a key molecule involved in the oxidative stress response and the vasodilation of blood vessels, both of which are essential for maintaining proper placental circulation.[9,10] Furthermore, increased branched-chain and aromatic amino acids, such as valine, isoleucine, and histidine, have been associated with insulin resistance. Moreover, insulin resistance has been linked to preeclampsia.[19,20]

This study contributes to understanding the relationship between macronutrient intake, specifically protein, and plasma amino acid levels during pregnancy. However, it has several limitations, including a small sample size and the absence of maternal and neonatal outcome tracking. Future research with larger populations is necessary to confirm these findings and explore the long-term effects of protein intake and amino acid levels on pregnancy outcomes. Additionally, this study highlights the importance of promoting freshwater fish consumption as a sustainable and culturally appropriate protein source in the Jambi region

In conclusion, pregnant women with adequate protein intake demonstrate higher plasma essential amino acid levels, particularly lysine. These findings underscore the importance of adequate protein intake during the first trimester to support maternal health and fetal development. Further research is needed to examine how amino acid requirements change across pregnancy and how plasma levels correlate with maternal and neonatal outcomes. This study offers valuable insights for improving nutritional counseling and public health strategies aimed at promoting optimal maternal nutrition, ultimately contributing to better pregnancy outcomes and long-term health for both mothers and their children.

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