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Evaluation of amino acid composition in different types of meat and plant-based burger patties

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Abstract: The study examined the protein content and amino acid composition of various commercially available plant-based and meat-based burger patties. The aim of this study was to determine whether plant-based burger patties meet the requirement for essential amino acid content in the human diet. Amino acid profiles were determined using the Amino Acid Analyzer and FAO/WHO guidelines were considered for essential amino acid requirements. In this study, the protein content and amino acid composition of various meat-based burger patties (ABB), including chicken, pork and beef, and plant-based burgers (PBB) were analysed. The results showed that among the plant-based samples, PBB 4 had the highest protein content (24.81 g / 100 g), which was almost equal to that of ABB 1 (26.48 g / 100 g). The most abundant amino acids detected were Glu, Asp, Leu, Lys, Arg, Ser, Pro and Gly, with samples PBB 6, PBB 3 and ABB 1 having the highest concentrations. PBB 1 stood out as a valuable protein source with the highest content of essential amino acids (400.08 mg/g protein) among the plant-based burger patties. Some plant-based burger patties were deficient in essential amino acids, with PBB 3 and PBB 4 having the highest deficiency. The practical value of this study is that it helps people to make informed dietary choices.

Key words: human nutrition, essential amino acids, proteins, meat substitutes, plant-based burger patties, nutrition value

Določitev aminokislinske sestave mesnih in rastlinskih burgerjev

Izvleček: V študiji smo preučevali vsebnost beljakovin in aminokislinsko sestavo različnih komercialno dostopnih mesnih in rastlinskih burgerjev. Namen študije je bil ugotoviti, ali rastlinski burgerji izpolnjujejo zahteve po vsebnosti esencialnih aminokislin v humani prehrani. Aminokislinski profili so bili določeni z analizatorjem aminokislin, kemijski indeksi posameznih esencialnih aminokislin za odrasle pa izračunani na podlagi smernic FAO/WHO. V študiji smo analizirali vsebnost beljakovin in aminokislinsko sestavo različnih mesnih burgerjev (ABB) iz piščančjega, svinjskega in govejega mesa ter burgerjev iz sestavin rastlinskega izvora (PBB). Rezultati so pokazali, da je imel med rastlinskimi vzorci PBB 4 najvišjo vsebnost beljakovin (24,81 g/100 g), ki je bila skoraj primerljiva z ABB 1 (26,48 g/100 g). Najbolj zastopane aminokisline v vzorcih so bile Glu, Asp, Leu, Lys, Arg, Ser, Pro in Gly, pri čemer so bile najvišje koncentracije le-teh izmerjene v vzorcih PBB 6, PBB 3 in ABB 1. PBB 1 se je pokazal kot dober vir beljakovin z najvišjo vsebnostjo esencialnih aminokislin (400,08 mg/g beljakovin) med rastlinskimi burgerji. Pri nekaterih rastlinskih burgerjih je bilo ugotovljeno pomanjkanje esencialnih aminokislin, največje pri vzorcih PBB 3 in PBB 4. Praktična vrednost te študije je v tem, da ljudem pomaga sprejemati premišljene prehranske odločitve.

Ključne besede: humana prehrana, esencialne aminokisline, beljakovine, mesni nadomestki, rastlinski burgerji, prehranska vrednost

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1 INTRODUCTION

The traditional meat industry is reaching production limits and is associated with environmental problems (*e.g.* impact on natural resources, greenhouse gas emissions, and use of land mass) (Godfray et al., 2018). Therefore, alternative protein sources, particularly plant-based meat analogues, are becoming increasingly popular as a potential solution to reduce the supply gap and environmental impact of conventional meat production. The popularity of plant-based meat substitutes valued for its ability to mimic traditional meat products reflects a broader trend among consumers seeking sustainable and environmentally friendly food options. The study addresses the nutritional aspects of meat and meat substitutes, aligning with the current imperative to address the environmental consequences of dietary choices. This study contributes to informing people about the quality of alternative protein sources.

A balanced diet is a key factor in human life and well-being. It consists of various foods from which humans obtain the nutrients necessary for health and the performance of vital functions (Ahmad et al., 2018). As an important food group that contributes to a balanced and healthy diet, meat and its products are a rich source of nutrients (Pereira & Vicente, 2022). However, meat consumption is considered unfavorable by some due to its presumed impact on the environment, ethics, and certain religious traditions. Customer awareness of sustainability and environmentally-friendly food production practices is growing and there are trends towards adopting vegetarian or vegan diets or limiting meat consumption (Graça et al., 2019).

An alternative could be plant-based meat analogues, which are plant-derived foods that have the sensory and chemical properties of traditional meat products (Ismail et al., 2020). While not all meat analogues fall under the classification of ultra-processed foods, a significant number of modern meat analogues available in the food market today meet this criterion. Ultra-processed foods are food products that contain minimal or no whole foods and are instead produced with processed ingredients or substances that are obtained from whole foods. These processed ingredients can include protein isolates, oils, hydrogenated oils and fats, flours and starches, sugar variants, refined carbohydrates, and other added ingredients that increase the value of the product (Bohrer, 2019; Monteiro et al., 2019). Ultra-processed foods are associated with an increased risk of obesity, cardiovascular diseases, and metabolic disorders due to high quantity of added sugars, harmful fats, and low nutritional value (Monteiro et al., 2013). Some consumers prefer modern meat analogues because they fulfill their expectations by imitating meat in terms of appearance, quality, and taste.

According to the forecast of the International Institute for Sustainable Development, the number of people on our planet will reach 9.9 billion by 2050 (Population Reference Bureau, 2020). Feeding such a mass population with meat could have a detrimental effect on the environment. The benefits of reducing meat consumption are therefore manifold. Environmental studies have been conducted on protein-rich products, including plant-based meat analogues (soybeans, green peas, lupines, rice, etc.), animal proteins (milk, meat, insects, lab-produced proteins), and mycoproteins. Most studies have shown that plant-based meat analogues have less environmental impact than meat analogues that include a broader range of substitutes, including plant-based, fungi-based, and cultured meat products that appeal to a wider audience (Kyriakopoulou et al., 2019).

Meat and its products are primary sources of protein and provide complete proteins containing all essential amino acids such as phenylalanine, valine, threonine, tryptophan, isoleucine, methionine, histidine, leucine and lysine. Complete proteins, which are found in animal foods such as eggs, milk, fish and meat, have the correct ratio of essential amino acids, making them sufficient sources of protein. Incomplete proteins lack some essential amino acids (Arentson-Lantz et al., 2021), but can be complemented by combining different incomplete or complete protein sources. Secondary proteins, commonly found in plants, may be deficient in some essential amino acids. Adequate dietary proteins are crucial at every stage of life and ensure the uptake of essential amino acids (Brestenský et al., 2019). For example, cereal proteins with low lysine content and legumes with a lack of sulphur-containing amino acids (methionine and cysteine) pose a challenge for the utilisation of proteins in the human body. The amino acid composition and digestibility of proteins from different plant sources are therefore of crucial importance. Studies by Day et al. (2022) and Foschia et al. (2017) on plant proteins as meat analogues emphasize the optimal mixture of certain grains and legumes to achieve a meat-like amino acid profile.

This study aimed to detect amino acids in different burger patties (plant- and animal-based). In addition, this study investigated whether plant-based meat substitutes (vegetable-based meats) meet the daily requirements for the intake of proteins and essential amino acids in the human diet when consuming these products.

2 MATERIAL AND METHODS

2.1 BURGER SAMPLES

Burger samples were collected from ten fast-food restaurants in Budapest, Hungary, during the study period of March–September 2023. A total of 50 burger samples of meat-based burgers (ABB) and plant-based burgers (PBB) were analyzed, with five samples for each type of burger. The patties of animal origin included chicken, pork, and beef, coded as ABB 1, ABB 2, ABB 3 and ABB 4. For the plant-based burgers, six different types were taken for analysis: PBB 1, PBB 2, PBB 3, PBB 4, PBB 5, and PBB 6 (Table 1). Samples were independently collected to ensure no cross-contamination and stored at −20 °C. The quality standards used for testing were based on the Crown Food Group – CFG (2023).

2.2 AMINO ACID DETERMINATION

Protein-building amino acids were detected as described by Berisha et al. (2023). Briefly, 500 mg portions of burger patties were subjected to hydrolysis in a vessel containing 10 mL of 6 mol L-1 hydrochloric acid, while being exposed to a nitrogen atmosphere at a temperature of 110 °C for a duration of 24 hours in a controlled thermostat. The process of neutralization was carried out in a 25 ml volumetric flask by adding 10 ml of a 4 M L-1 NaOH solution to the hydrolyzed sample. The flask was then filled with buffer solution at a pH of 2.2. The samples that had been neutralized were passed through a membrane filter with a pore size of 0.25 µm. The determination of amino acids was conducted using a AAA400 Automatic Amino Acid Analyzer (Ingos Ltd., Prague, Czech Republic), which was equipped with a cation-exchange column. The separation was carried out using a stepwise gradient elution technique with lithium buffer systems. Following post-column derivatization using a ninhydrin reagent, colorimetric detection was performed at wavelengths of 570 nm and 440 nm specifically for Pro. Three samples were produced in parallel for analysis (Berisha et al., 2023).

2.3 AMINO ACID SCORE CALCULATION

The calculation of the essential amino acids scores or the so-called chemical score is done using the formula given by WHO (1991), equation 1, expressed either as a ratio of unity (recommended) or on a percentage scale (Food and Agriculture Organization Expert Working Group, 2018).

$$Amino\ Acid\ Score = \frac{\text{mg of amino acid in 1 g of the tested protein}}{\text{mg of amino acid in 1 g of the reference protein}} \quad (1)$$

Reference protein amounts are shown in three

Table 1: Ingredients for plant-based burger patties

Burger type	Composition
PBB 1	Water, 18% pea protein, rapeseed oil, refined coconut fat, rice protein, natural flavour, dry yeast, butter, emulsifier: methylcellulose, less than 1% potato starch; table salt, potassium chloride, beetroot concentrate, apple extract, pomegranate concentrate, sunflower lecithin, food vinegar, lemon concentrate, vitamins and minerals (zinc sulfate, niacin [vitamin B3], pyridoxine [vitamin B6], cobalamin [B12]) pantothenic acid [vitamin B5].
PBB 2	Water, 20% pea protein, diced onion, sunflower oil, diced turnip, stabilizer: methylcellulose, pea fiber, potato starch, vinegar, maple syrup, spices, beet syrup, edible salt, smoked lemon concentrate.
PBB 3	Water, 14% soybean meal, carrot, refined coconut fat, wheat flour, 4% wheat protein, rapeseed oil, acidity regulator: potassium lactate, potassium acetate; emulsifier: methylcellulose, yeast extract, flavouring, green pea starch, soy protein, table salt, spices, beetroot with colouring effect, mushroom powder, spice extracts, smoke flavour.
PBB 4	Water, 11.8% soy protein, 9.9% wheat protein, carrot, refined coconut fat, rapeseed oil, emulsifier: methylcellulose, spices, yeast extract, flavouring, starch, natural flavour, acidity regulator: potassium lactate, acetate; table salt, vinegar, beet concentrate with colouring effect, bamboo fiber, spice extracts, smoke flavour, food acid: citric acid, antioxidant: ascorbic acid.
PBB 5, PBB 6	ABB4, PBB5, PBB6 the proportions of the ingredients in the patty and their full list are secret. However, the ABB4 is known to be made from beef, the PBB5 is made primarily from potatoes, carrots, green peas and corn, while the PBB6 is made from soy and wheat from sustainable farms.

Source: adjusted from food product label groups: ages 3–14 years, 15–18 years, and more than 18 years, approved by FAO (2013). In this research, the ratio of essential amino acids for adults (over 18 years) was evaluated.

2.4 ESSENTIAL AMINO ACID DEFICIENCY INDEX CALCULATION

The essential amino acid deficiency index is determined by calculating the differences in the essential amino acid value compared to the reference protein (Table 2).

Table 2: Procedure for calculating the essential amino acid (EAA) deficiency index

Essential amino acids (EAA)	Reference protein (mg/g)	ABB4 (mg/g protein)	EAA score	Calculation 1 – EAA score	Index of EAA deficiency
Histidine	16	31.29	1.96	1–1.96	−0.96
Isoleucine	30	22.36	0.75	1–0.75	0.25
Leucin	61	79.80	1.31	1–1.31	−0.31
Lysine	48	82.06	1.71	1–1.71	−0.71
Methionine and Cysteine	23	18.66	0.81	1–0.81	0.19
Phenylalanine and Tyrosine	41	64.75	1.58	1–1.58	−0.58
Threonine	25	46.02	1.84	1–1.84	−0.84
Valin	40	37.78	0.94	1–0.94	0.06

If the EAA deficiency index is positive, this means that the amino acid is present in the sample in a lower proportion than the amino acid of the reference protein. If it is negative, there is a surplus. The deficit is therefore indicated by positive values. The sum of these positive values gives the essential amino acid deficiency index. The calculation procedure is shown in Table 2 for the samples of ABB4 burgers; this procedure was used for all analyzed burger types.

3 RESULTS

3.1 PROTEIN CONTENT ON MEAT PATTY AND PLANT-BASED MEAT ANALOGUES

The total protein content of the samples was calculated using the results of the amino acid analysis (Table 3). Tryptophan is not included in the amino acid values obtained by chromatography, as its indole group is degraded by the acidic sample preparation, so that this amino acid cannot be detected by this method. Due to the variety of ingredients in burger patties, there is no information in the literature on their tryptophan content. The main components of the analyzed plant products can be classified as legumes, which are characterized by the limiting amino acid in the group of sulfur-containing amino acids (Met + Cys), so that the lack of tryptophan values does not pose a problem in the evaluation. This essential amino acid is rather limiting in maize.

Table 3 shows the total protein content of the samples per 100 g of product and the standard deviation of the analyzed samples. The protein content of the ABB1 is 26.48 g / 100 g. The highest value of veggie patties is the PBB 3 (24.81 g / 100 g), approaching the protein content of the ABB 1 and surpassing all three meat samples in terms of protein. This burger contains 14 % soy flour, 4 % wheat protein, and mushrooms also contribute to the development of favorable protein content, so the product can be considered a good substitute for meat in this regard. The lowest protein, only 4.34 g / 100 g, is found in the PBB 5.

Table 3: Total protein content of samples per 100 g of product

Type of burger patty	Protin Content (g/100 g) ± standard deviation (n = 3)
PBB 1	16.96 ± 0.54
PBB 2	15.76 ± 0.42
PBB 3	24.81 ± 2.23
PBB 4	12.90 ± 2.81
PBB 5	4.34 ± 0.44
PBB 6	24.72 ± 2.15
ABB 1	26.48 ± 2.24
ABB 2	22.74 ± 0.72
ABB 3	18.26 ± 0.22
ABB 4	19.14 ± 0.18

3.2 PROTEIN-BUILDING AMINO ACIDS

The results for the composition of protein-forming amino acids in plant-based burger patties are presented in Table 4. The main amino acids detected in the analyzed samples include Glu, Asp, Leu, Lys, Arg, Ser, Pro, and Gly which account for more than 50 % of the total amount of amino acids detected. By comparing the total amount of amino acids detected in plant-based burger patties, it was found that the PBB 6 (247.21 mg/g) had the highest amount of the amino acids, followed by PBB 3 (248.1 mg/g). The lowest amount of amino acids was detected in PBB 5 (43.42 mg/g).

Table 6 shows that PBB 1 with 400.08 mg/g protein has the highest total content of essential amino acids among the plant-based samples. PBB 2 and PBB 6 contain 381.57 mg/g and 351.96 mg/g, respectively, while PBB 3 has the lowest total essential amino acid content at 304.01 mg/g protein. PBB 2, containing highest proportion of pea protein, has the highest content of leucine and isoleucine among the plant-based variants and is therefore a good source of these essential amino acids. PBB 3 has the lowest proportion of branched-chain amino acids, which make up around a third of the essential amino acids in muscle tissue. PBB 3, PBB 4, PBB 5 and PBB 6, which contain wheat protein, have a lower lysine content than the other two plant-based meat analogues. This is because lysine is the limiting amino acid in whole grains. According to the product label (Table 1), the soy flour content in the PBB 3 patty was higher (14 %) than in the PBB 4 patty (11.8 %). This is due to the fact that soy supplements the missing lysine content in wheat flour, which could explain the higher lysine content (42.35 mg/g and 39.29 mg/g respectively). The methionine content was relatively low in all plant-based products, as they contained a high proportion of pulses, which are low in sulphur-containing amino acids such as methionine and cysteine. The PBB 3 patties contained the highest level of sulphur-

Table 4: Amino acid composition of plant-based burger patties (mg/g)

Amino acids	PBB 1	PBB 2	PBB 3	PBB 4	PBB 5	PBB 6
Glutamic acid	38.36	35.98	86.72	42.17	10.34	67.59
Aspartic acid	19.46	18.53	18.53	9.85	5.52	24.33
Leucine	15.24	14.26	14.33	10.16	2.84	21.02
Lysine	13.1	11.75	10.49	5.04	2.29	13.94
Arginine	12.61	14.15	10.64	6.85	2.39	17.4
Serine	10.09	9.43	13.6	6.83	2.37	13.11
Proline	8.3	5.37	23.33	13.33	2.59	15.19
Glycine	8.24	7.38	10.86	5.4	2.12	12.49
Phenylalanine	7.52	7.39	9.99	5.47	1.59	10.95
Threonine	7.48	6.65	8.14	5.18	2.14	9.78
Valina	6.91	6.04	7.64	4.3	1.83	9.33
Alanine	6.87	6.63	9.25	4.24	2.39	9.97
Tyrosine	5.73	5.41	11.6	3.95	2.43	8.15
Histidine	4.26	3.95	7.24	2.82	1.64	6.35
Isoleucine	4.24	3.99	3.87	2.68	0.7	6.21
Methionine	1.17	0.69	1.84	0.74	0.23	1.4
Sum mg/g	169.6	157.6	248.1	129	43.42	247.21

Table 5 shows the results for the amino acid composition of meat-based burger patties (ABB). Amino acids such as Glu, Gly, Asp, Lys, Leu, Arg, Ala, Thr, and Ser were detected in the highest amounts in these burgers. ABB 1 (264.82 mg/g), and ABB 2 (227.4 mg/g) had the highest amount of amino acids, followed by beef burgers (191.41 mg/g), while the lowest amount of amino acids was detected in pork burgers (182.64 mg/g).

The total essential amino acid content is presented in Tables 6 and 7. All types of analyzed burgers contained all essential amino acids. Essential amino acids are present in plant products in amounts between 304.01 to 400.08 mg/g of protein.

Table 5: Amino acid composition of meat-based burger patties (mg/g)

Amino acids	ABB 1	ABB 2	ABB 3	ABB 4
Glutamic acid	53.23	46.65	36.59	34.47
Glycine	26.30	9.11	7.71	11.62
Aspartic acid	24.09	20.68	16.14	18.72
Lysine	21.71	22.07	17.42	15.91
Leucine	21.16	22.85	18.43	16.26
Arginine	19.54	17.68	14.27	12.46
Alanine	17.47	11.23	8.59	10.68
Threonine	12.20	12.16	9.30	9.26
Serine	12.03	10.16	7.71	8.08
Proline	10.80	6.38	4.35	9.49
Valine	10.00	10.97	8.20	10.77
Phenylalanine	9.23	10.00	8.04	6.45
Histidine	8.27	4.44	7.83	6.75
Tyrosine	7.92	8.28	6.60	5.68
Isoleucine	5.93	7.62	6.04	7.84
Methionine	4.93	7.14	5.42	6.98
Sum mg/g	264.82	227.40	182.64	191.41

containing amino acids (7.52 mg/g) and the lowest level in PBB 2 (4.36 mg/g). PBB 2 has the highest content of legume protein (20 % pea protein) and some other vegetables (turnips and onions), which explains the low value of the limiting amino acid.

Table 7 shows the content of essential amino acids in meat-based burgers. The ABB 1, made from raw animal material, contains 382.72 mg/g of protein, while the ABB 2, ABB 3, and ABB 4 contain higher amounts, ranging from 409.36 to 477.70 mg/g of protein.

In general, plant-based products do not fall significantly short of the total amino acid content of a traditional animal-based burger.

3.3 ESSENTIAL AMINO ACIDS SCORE AND LIMITING AMINO ACIDS

The amount of each essential amino acid in mg/g protein in each sample was divided by the amount of mg/g protein of each of the essential amino acids of the FAO/WHO reference protein to give the score for each essential amino acid (EAAS- essential amino acid score). The closer this score is to 1 for each essential amino acid, the more the food corresponds to the FAO/WHO reference protein composition. If the essential amino acid has a ratio less than l then it is counted as the limiting amino acid.

Table 6: Essential amino acid composition of plant-based samples (mg/g protein)

Essential amino acids	PBB 1	PBB 2	PBB 3	PBB 4	PBB 5	PBB 6
Histidine	25.15	25.05	29.00	22.12	37.23	25.68
Isoleucine	25.03	25.30	15.75	20.60	16.46	25.10
Leucine	89.94	90.49	58.89	79.07	66.40	84.96
Lysine	89.94	74.61	42.35	39.29	53.08	56.27
Methionine	6.90	4.36	7.52	6.02	5.40	5.50
Phenylalanine and Tyrosine	78.16	81.23	87.04	73.06	92.65	77.27
Threonine	44.16	42.21	32.67	40.40	49.09	39.51
Valine	40.80	38.32	30.79	33.68	42.17	37.67
Sum	400.08	381.57	304.01	314.24	362.48	351.96

Table 7: Essential amino acid composition of animal-based samples (mg/g protein)

Essential amino acids	ABB 1	ABB 2	ABB 3	ABB 4
Histidine	31.29	19.67	42.86	35.29
Isoleucine	22.36	33.46	33.03	40.96
Leucine	79.80	100.44	100.87	84.95
Lysine	82.06	97.04	95.37	83.11
Methionine	18.66	31.37	29.66	36.51
Phenylalanine and Tyrosine	64.75	80.35	80.13	63.33
Threonine	46.02	53.40	50.90	48.38
Valine	37.78	48.19	44.90	56.40
Sum	382.72	463.92	477.72	431.05

The results for the essential amino acid score are shown in Table 8 for plant-based burger patties and in Table 9 for animal-based burger patties, in which the limiting amino acids are marked.

The amino acids methionine and cysteine, which are normally found in larger quantities in meat, are the limiting amino acids in all plant-based burger patties, which contain significant amounts of legumes. The lowest amount is found in PBB 2, which contains 20 % pea protein. The ABB 1 patty contains three essential amino acids (isoleucine, methionine and valine) with a value of less than 1 compared to the FAO/WHO reference proteins. It can be assumed that a vegetable protein-based additive was added to the minced meat as an enhancer, binder or fat substitute, which can be measured as protein together with the meat content of the sample, resulting in values for essential amino acids below 1.

Among meat-free products, PBB 3 has the highest protein content per 100 g, but qualitatively it is considered the most unfavorable source of protein, as it has

Table 8: Essential amino acids score and limiting amino acids of plant-based burger samples

Essential amino acids	PBB 1	PBB 2	PBB 3	PBB 4	PBB 5	PBB 6
Histidine	1.57	1.57	1.81	1.38	2.33	1.60
Isoleucine	0.83	0.84	0.52	0.69	0.55	0.84
Leucine	1.47	1.48	0.97	1.30	1.09	1.39
Lysine	1.87	1.55	0.88	0.82	1.11	1.17
Methionine and Cysteine	0.30*	0.19*	0.33*	0.26*	0.23*	0.24*
Phenylalanine and Tyrosine	1.91	1.98	2.12	1.78	2.26	1.88
Threonine	1.77	1.69	1.31	1.62	1.96	1.58
Valine	1.02	0.96	0.77	0.84	1.05	0.94

Table 9: Essential amino acids score and limiting amino acids of meat-based burger samples

Essential amino acids	ABB 1	ABB 2	ABB 3	ABB 4
Histidine	1.96	1.23	2.68	2.21
Isoleucine	0.75*	1.12	1.10	1.37
Leucine	1.31	1.65	1.65	1.39
Lysine	1.71	2.02	1.99	1.73
Methionine and Cysteine	0.81	1.36	1.29	1.59
Phenylalanine and Tyrosine	1.58	1.96	1.95	1.54
Threonine	1.84	2.14	2.04	1.94
Valine	0.94	1.20	1.12	1.41

low levels of essential amino acids (isoleucine, leucine, lysine, methionine, valine), compared to the reference protein. PBB 1 and PBB 5 are deficient only in methionine and isoleucine. The amount of histidine, phenylalanine, tyrosine, as well as threonine, is above the minimum values determined by FAO/WHO experts.

3.4 ESSENTIAL AMINO ACID DEFICIENCY INDEX

The greatest deficiencies in essential amino acids were found in PBB 3 (1.53) and PBB 4 (1.39) (Table 10). PBB 5, which probably contains mainly potatoes, was not the worst product due to the added egg content, but still showed a large deficit of 1.22. PBB 2 and PBB 6 have almost identical values of 1.01 and 0.98, respectively. Although PBB 1 is deficient in only 2 essential amino acids, their sum amounts to 0.87. Since the total ratio of essential amino acids in most meat-based burgers is above 1 (Table 9), their essential amino acid deficiency index is 0. However, ABB 1 has a deficiency of 0.50, which may be due to the addition of vegetable protein-based additives. The ratios of the essential amino acids threonine (2.14), lysine (2.02), phenylalanine and tyrosine (1.96), leucine (1.65) in ABB 2, histidine (2.68), threonine (2.04), lysine (1.9), phenylalanine and tyrosine (1.95), leucine (1.65) in ABB 3, histidine (2.21), threonine (1.94), lysine (1.73), methionine (1.59), phenylalanine and tyrosine (1.54) in ABB 4 are much higher than those of the reference protein. Most of the plant-based samples contain less methionine, isoleucine and valine. In PBB 4, the amount of lysine is also below the recommended value, while in PBB 3 the leucine content is suboptimal compared to the reference protein.

Table 10: Index of the deficiency of essential amino acids of the samples compared to the reference protein

Type of burger	Index of the deficiency of essential amino acids
PBB 1	0.87
PBB 2	1.01
PBB 3	1.53
PBB 4	1.39
PBB 5	1.22
PBB 6	0.98
ABB 1	0.50
ABB 2	0.00
ABB 3	0.00
ABB 4	0.00

4 DISCUSSION

The amino acid composition of meat-based burger patties and plant-based burger patties can be very different, primarily depending on the protein source. Meat-based burger patties typically provide more complete and balanced protein nutrition, including essential vitamins and minerals naturally present in meat, while plant-based meat analogues vary based on the ingredients used in their formulation, as in the study conducted by Day et al. (2022). Meat and its products are thought to have been part of the human diet from 2–6 million years ago and increased over time as a result of increases in income and population number. However, the trend towards the use of plant-based meat substitutes in the human diet is increasing (Godfray et al., 2018; Filin et al., 2023).

When comparing meat-based burger patties and plant-based burger patties, consumers should consider their dietary goals, preferences, and ethical concerns. If someone relies heavily on meat analogues, they may need to supplement their diet to ensure they are getting all the essential amino acids. It is also important to know the specific amino acid composition of the two types of burger patties and how it meets nutritional needs and individual health status. A study conducted by Bryant *et al.* (2019) examined the consumer acceptance of plant-based and clean (cultured) meat products in the United States, China, and India. The findings indicate that urban, well-educated, and high-income consumers in India and China demonstrate a higher propensity to purchase clean meat and plant-based meat compared to consumers in the USA. The research conducted by Ismail et al. (2020) also highlights a significant bias towards urban, educated, and wealthy groups in China and India, as opposed to the overall population. The study revealed that disgust plays a crucial role in determining the adoption of plant-based and clean meat, a distinctive observation limited to the United States. In China, there is a notable deviation from the generally observed demographic pattern in the Western countries regarding the acceptance of clean meat, particularly in relation to gender. The attitudinal factors influencing the acceptance of both plant-based and clean meat in China include perceptions of healthiness, nutritional value, excitement, goodness, and necessity. Given the recommended dietary allowance (RDA) for protein intake in adults is 0.8 grams per kilogram of body weight per day (Nishimura et al., 2023) and incorporating these plant-based options can help meet protein needs without the associated health risks of excessive red meat consumption. High intake of red meat, particularly processed varieties, has been linked to increased risks of chronic diseases such as cardiovascular disease, type 2 diabetes, and certain cancers due to its saturated fat, cholesterol content, and potential carcinogens formed during cooking (Fogelholm et al., 2015; Larsson and Orsin., 2014; Zheng et al., 2019).

The analysis of various burger patties used in popular fast-food offerings reveals that these meat substitutes can be made from a variety of plant-based ingredients, such as soy, peas, beans, or mushrooms, and may serve as satisfactory protein substitute in the human diet, as they contain all essential amino acids. However, it should be noted that while meat contains a balanced profile of essential amino acids, plant-based burger patties (*i.e.* legume-based meat analogues) are often deficient in amino acids, as methionine, lysine, and cysteine. PBB 1 stands out as a valuable protein source among these options due to its high content of essential amino acids. A review paper by Kyriakopoulou et al. (2021) in functionality of ingredients in plant-based meat analogues showed that the main ingredients in commercial meat analogues are soy, pea, and gluten, which are widely available, and by-products of established food production lines.

This provides additional opportunities to enhance functionality and optimize resource utilization. For example, pea protein and rice protein can be combined to create a complete amino acid profile, making the product more nutritionally comparable to animal protein. Similarly, combining soy protein with wheat gluten can improve the texture and binding properties of meat substitutes, as noted by Asgar et al. (2010). Additionally, the incorporation of algae or seaweed extracts can enhance the nutritional value and provide unique flavours and textures (Abdel-Moatamed et al., 2024; Schuler et al., 2020). These combinations not only enhance functionality but also optimize resource utilization, opening new possibilities for sustainable and nutritious food products.

The shift towards individual dietary patterns such as vegetarian or vegan diets is now being driven by a variety of factors, including health concerns about saturated fats in animal products, environmental impact, greenhouse gas emissions, climate change and ethical concerns about animal husbandry and slaughter practices. However, consumers may need to pay more attention to their overall diet to ensure they are getting all the essential amino acids. In addition, a combination of plant and animal proteins can be explored to produce healthy burger patties that meet essential amino acid requirements while reducing saturated fat content from animal products. The evaluation of amino acid composition highlights the importance of considering the overall quality of the protein and the completeness of the nutritional content when choosing between meat-based and plant-based burger patties. It is crucial to educate consumers about the differences in amino acid composition and the nutritional impact of choosing between meat and meat substitutes to help them make dietary choices in line with their needs and preferences. Ongoing research to improve the amino acid composition of meat substitutes and fortify them with essential nutrients could bring products closer to meat products and have a siginificant impact on the food industry.

5 CONCLUSIONS

This study provides a comprehensive analysis of the protein content and amino acid composition of a wide variety of burger patties, including both plant-based and meat-based options. The results of the amino acid composition studies showed a wide range of amino acids in the products, with the major amino acids Glu, Asp, Leu, Lys, Arg, Ser, Pro, and Gly accounting for more than half of all amino acids found. The analysis of the protein composition revealed that plant-based substitutes *(e.g.* PBB 3) can have competitive protein levels comparable to those of traditional meat products. Certain differences in the composition of essential amino acids were found, especially in the plant-based patties with lower amounts of methionine and lysine. Plant-based patties with a high proportion of legumes had limiting values for cysteine and methionine, confirming their status as limiting amino acids. However, it is also important to consider the bioavailability of proteins. Factors that affect the bioavailability of plant-based proteins include the presence of antinutritive factors such as phytates, which can inhibit mineral absorption, and the protein matrix itself, which can affect digestion and absorption. Although the amino acid profiles and protein content of plant-based burgers are promising, further bioavailability studies are needed to fully understand their nutritional impact. The results of the study point to the potential of mixing animal and plant protein sources to address the lack of essential amino acids in plant-based burger patties. This approach could reduce meat consumption while ensuring adequate nutrient intake. This study aims to provide information to make better dietary decisions.

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