

BRIEF COMMUNICATION

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The potential renal acid load of plant-based meat alternatives

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Plant-based meat alternatives (PBMA) are food products derived from plants and designed to mimic the preparation methods, nutritional profile, and sensorial qualities of meat. PBMA are currently subject to a controversial debate concerning their health value. Here, we reviewed PBMA's potential renal acid load (PRAL). The PRAL is an estimate for the amount of acid or base a certain food produces in the human body, and was associated with tissue damage and acid stress. PRAL values varied substantially across the examined foods, and differences were as large as 19.73 mEq per 100 g of PBMA. Mycoprotein- and wheat-based PBMA were more acidic than conventional meats. The majority of items, however, exerted a lower PRAL to the human kidneys when compared to their meat-based counterparts. Our findings reiterate that not all PBMA are created equal, and suggest that PBMA are generally not suitable to substantially alkalize an individual's diet.

European Journal of Clinical Nutrition (2024) 78:732–735; <https://doi.org/10.1038/s41430-024-01434-8>

INTRODUCTION

Plant-based diets enjoy growing popularity in many Western countries [1]. As opposed to 'traditional' whole-food plant-based diets, the fast-paced nature of contemporary lifestyles has drastically increased the demand for plant-based convenience foods [2]. Plant-based meat alternatives (PBMA) are commercially available food products, which were derived from plant, and which were designed to mimic the preparation methods, sensorial qualities and nutritional profile of meat-based equivalents (MBEs).

As novel food items, PBMA are subject to a controversial debate concerning their health value [2, 3]. This debate mainly focused on nutritional profiles but has rarely covered PBMA's acid-based impact [4].

The Potential Renal Acid Load (PRAL) score is an estimate for the amount of acid or base a certain food produces in the body [1]. High-PRAL foods exert a substantial acid load to the human kidneys, and may promote tissue inflammation and low-grade acidosis when consumed over a long time. They were also associated with cardiovascular disease, diabetes and altered cortisol metabolism in numerous studies [1].

Based on the current knowledge of PBMA's nutrient profiles [2], we hypothesized that PBMA would differ in PRAL scores in comparison to their MBEs. To test this hypothesis, we performed a secondary data analysis and estimated the PRAL value of the most commonly consumed PBMA.

MATERIALS AND METHODS

Food item collection

This brief contribution builds on published data from other sources. We used PubMed and Google Scholar to identify scientific articles that investigated the nutrient content of PBMA. We performed search queries with combinations of the following keywords: "meat analog", "plant-based meat", "meat alternative", "nutrient content", and "nutritive value". For

PRAL estimation, nutrient content data of the following nutrients was required: protein, magnesium, potassium, calcium and phosphorus. Thus, only sources that covered these particular nutrients were considered. Based on our criteria, we identified 3 articles from which we extracted data [5–7]. For reference purposes, we calculated the PRAL value of common meats using data from FoodData Central [8].

PRAL estimation

Our methods for PRAL estimation have been described in related publications [9]. In brief, we used the formula by Remer and Manz to calculate PRAL in mEq/100 g portions [10]. PRAL corrects for intestinal absorption of ingested minerals and sulfur-containing protein, and takes into account ionic dissociation [10]. Food items with a PRAL value > 0 exert acidifying properties, whereas a PRAL value < 0 indicates alkalizing effects [1].

$$\text{PRAL} = (0.49 * \text{protein intake (g/100 g)}) + (0.037 * \text{phosphorus intake (mg/100 g)}) - (0.021 * \text{potassium intake (mg/100 g)}) - (0.026 * \text{magnesium intake (mg/100 g)}) - (0.013 * \text{calcium intake (mg/100 g)})$$

Statistical analysis

We described relevant statistical procedures elsewhere in detail [9]. Data was analyzed with STATA 14 statistical software. Based on Stata's Shapiro–Wilk test, we decided whether data was normally distributed or not. Pearson's product-moment correlations were run to assess the relationship between nutrient contents and PRAL.

RESULTS

As part of the secondary data analysis of Harnack et al. [5], we analyzed the PRAL value of $n = 37$ plant-based ground beef alternatives (Table 1). PRAL values varied substantially across the examined foods, and ranged from -2.89 mEq/100 g to 16.84 mEq/100 g. The mean PRAL value was 4.04 ± 4.73 mEq/100 g and thus suggested a moderately acidifying potential (PRAL > 0 mEq/d). Almost 80% of the examined items had a PRAL value < 8 mEq/100 g,

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Received: 9 November 2023 Revised: 12 March 2024 Accepted: 13 March 2024

Published online: 19 March 2024

Table 1. Nutrient content and PRAL values of selected plant-based ground beef alternative products in the United States.

| Product name | Producer | Vegan | Protein | Ca | K | Mg | P | PRAL |
|---|-----------------------|-------|---------|--------|--------|-------|--------|-------|
| All American Veggie Burger | Amy's Kitchen, Inc. | Yes | 15.88 | 61.18 | 276.47 | 54.35 | 191.18 | 6.84 |
| Organic Black Bean Veggie Burger | Amy's Kitchen, Inc. | Yes | 8.47 | 30.59 | 442.35 | 54.35 | 161.76 | -0.96 |
| Organic California Veggie Burger | Amy's Kitchen, Inc. | Yes | 8.82 | 45.88 | 331.76 | 64.24 | 191.18 | 2.16 |
| Organic California Veggie Burger, Light in Sodium | Amy's Kitchen, Inc. | Yes | 8.82 | 45.88 | 331.76 | 64.24 | 191.18 | 2.16 |
| Organic Sonoma Veggie Burger, Gluten Free, Dairy Free | Amy's Kitchen, Inc. | Yes | 6.24 | 30.59 | 331.76 | 64.24 | 176.47 | 0.55 |
| Organic Summer Harvest Veggie Burger | Amy's Kitchen, Inc. | Yes | 5.65 | 61.18 | 276.47 | 69.18 | 147.06 | -0.19 |
| Quarter Pound Veggie Burger | Amy's Kitchen, Inc. | Yes | 17.29 | 76.47 | 331.76 | 49.41 | 161.76 | 5.21 |
| Beyond Beef | Beyond Meat | Yes | 18.00 | 15.29 | 276.47 | 34.59 | 147.06 | 7.36 |
| Beyond Beef Crumbles Beefy | Beyond Meat | Yes | 22.00 | 15.29 | 55.29 | 49.41 | 235.29 | 16.84 |
| Beyond Burger | Beyond Meat | Yes | 18.00 | 15.29 | 276.47 | 34.59 | 147.06 | 7.36 |
| Gardein Beefless Ground | Conagra, Inc. | Yes | 21.18 | 107.06 | 718.82 | 39.53 | 250.00 | 2.11 |
| Impossible Burger | Impossible Foods Inc. | Yes | 16.94 | 152.94 | 552.94 | 9.88 | 161.76 | 0.43 |
| Gardenburger Black Bean Chipotle Veggie Burgers | Kellogg NA Co. | Yes | 6.94 | 45.88 | 221.18 | 44.47 | 117.65 | 1.36 |
| Gardenburger Original Burgers | Kellogg NA Co. | No | 6.82 | 61.18 | 165.88 | 44.47 | 191.18 | 4.98 |
| Gardenburger Portabella Veggie Burgers | Kellogg NA Co. | No | 5.53 | 45.88 | 221.18 | 54.35 | 147.06 | 1.50 |
| Morningstar Farms Cheezeburger | Kellogg NA Co. | Yes | 20.71 | 91.76 | 165.88 | 9.88 | 132.35 | 10.11 |
| Morningstar Farms Chipotle Black Bean Crumbles | Kellogg NA Co. | Yes | 13.65 | 45.88 | 221.18 | 74.12 | 117.65 | 3.87 |
| Morningstar Farms Falafel Burgers | Kellogg NA Co. | Yes | 7.65 | 76.47 | 221.18 | 34.59 | 117.65 | 1.56 |
| Morningstar Farms Garden Veggie Burgers | Kellogg NA Co. | No | 16.35 | 91.76 | 221.18 | 39.53 | 88.24 | 4.41 |
| Morningstar Farms Grillers Crumbles | Kellogg NA Co. | Yes | 14.82 | 107.06 | 442.35 | 88.94 | 205.88 | 1.89 |
| Morningstar Farms Grillers Original Veggie Burgers | Kellogg NA Co. | No | 25.65 | 91.76 | 165.88 | 24.71 | 73.53 | 9.97 |
| Morningstar Farms Grillers Prime Veggie Burgers | Kellogg NA Co. | No | 22.59 | 61.18 | 165.88 | 19.76 | 117.65 | 10.63 |
| Morningstar Farms Meat Lovers Vegan Burgers | Kellogg NA Co. | Yes | 24.12 | 30.59 | 165.88 | 24.71 | 161.76 | 13.28 |
| Morningstar Farms Mediterranean Chickpea Burgers | Kellogg NA Co. | No | 15.65 | 76.47 | 276.47 | 44.47 | 102.94 | 3.52 |
| Morningstar Farms Roasted Garlic & Quinoa Burgers | Kellogg NA Co. | Yes | 10.71 | 61.18 | 552.94 | 44.47 | 147.06 | -2.89 |
| Morningstar Farms Spicy Black Bean Burgers | Kellogg NA Co. | No | 13.06 | 76.47 | 387.06 | 59.29 | 117.65 | 0.09 |
| Morningstar Farms Spicy Indian Veggie Burgers | Kellogg NA Co. | Yes | 9.53 | 61.18 | 497.65 | 29.65 | 132.35 | -2.45 |
| Morningstar Farms Tex-Mex Burgers | Kellogg NA Co. | Yes | 9.53 | 76.47 | 387.06 | 54.35 | 132.35 | -0.97 |
| Morningstar Farms Tomato & Basil Pizza Burgers | Kellogg NA Co. | No | 16.59 | 137.65 | 331.76 | 34.59 | 161.76 | 4.46 |
| Morningstar Farms Veggie Lovers Vegan Burgers | Kellogg NA Co. | Yes | 7.88 | 30.59 | 276.47 | 44.47 | 132.35 | 1.40 |
| Morningstar Farms White Bean Chili Veggie Burgers | Kellogg NA Co. | Yes | 11.88 | 91.76 | 552.94 | 49.41 | 147.06 | -2.83 |
| BOCA All American Veggie Burgers | Kraft Foods, Inc. | No | 18.71 | 137.65 | 165.88 | 19.76 | 191.18 | 10.45 |
| BOCA Original Veggie Crumbles | Kraft Foods, Inc. | Yes | 19.65 | 122.35 | 110.59 | 34.59 | 191.18 | 11.89 |
| Quorn Meatless Grounds | Marlow Foods Ltd. | No | 13.88 | 45.88 | 110.59 | 19.76 | 29.41 | 4.46 |
| Quorn Vegan Meatless Spicy Patties | Marlow Foods Ltd. | Yes | 12.24 | 30.59 | 110.59 | 19.76 | 29.41 | 3.85 |
| Plant-Based Crumbles Beef Style | Tofurky | Yes | 16.71 | 91.76 | 608.24 | 93.88 | 220.59 | -0.06 |
| Worthington Meatless Fripat | Worthington | No | 22.00 | 122.35 | 442.35 | 9.88 | 147.06 | 5.08 |

Data obtained and modified from Harnack et al. [5]. Nutrient content per 100 g cooked portions; PRAL value for a 100 g edible portion. PRAL in mEq/100 g. Protein in g/100 g. Calcium (Ca), Potassium (K), Magnesium (Mg) and Phosphorus (P) in mg/100 g. Note: Harnack et al. [5] reported nutrient content in mg and g/3 ounce cooked portions, which was used here to calculate nutrient contents of 100 g portions.

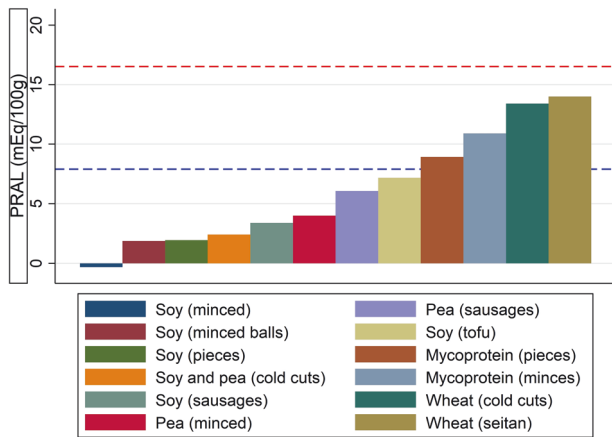


Fig. 1 PRAL values of selected plant-based meat alternative groups. legend: based on data from Ložnjak Švarc et al. [6]. Data based on a nutrient analysis of $n = 58$ products with protein derived from egg white, mycoprotein, pea, soy, a combination of pea and soy, and wheat. PRAL in mEq/100 g. The blue dotted line indicates the PRAL value of a 100 g portion of beef, whereas the red dotted line indicates the PRAL value of a 100 g portion of chicken.

and thus ranked lower than conventional pork and beef meat, which both have PRAL values of approximately 8 mEq/100 g.

The protein content per 100 g cooked portion ranged from 5.53 g to 25.65 g and was positively associated with PRAL ($r = 0.73$, $p < 0.001$). Significant inverse associations with PRAL were found for the magnesium ($r = -0.41$, $p = 0.01$) and potassium content ($r = -0.69$, $p < 0.001$). The “Beyond Beef Crumbles Beefy” and the “Morningstar Farms Meat Lovers Vegan Burgers” were the most acidifying food items, with PRAL values of 16.84 and 13.28 mEq/100 g, respectively.

Further to that, we used data from Ložnjak-Švarc, who performed a nutrient analysis of $n = 58$ products with protein derived from egg white, mycoprotein, pea, soy, a combination of pea and soy, and wheat [6]. Readily available on the Danish food market, these products were divided into several groups, such as cold cuts, minced, or sausages. We adopted this classification and calculated group-specific PRAL values (Fig. 1). The mean PRAL value in this food sample was 6.15 ± 4.76 mEq/100 g. The mycoprotein- and wheat-based food items yielded the highest PRAL values, ranging from 8.92 to 13.99 mEq/100 g.

Finally, we analyzed data from De Marchi et al., who compared selected Italian plant-based and meat-based burgers (Supplementary Table 1) [7]. The PRAL values between both groups did not differ substantially (6.80 vs. 7.27 mEq/100 g), probably because of the rather similar protein content of the examined items. While plant-based burgers were more abundant in potassium (an alkali precursor), they also included more acidifying phosphorus.

DISCUSSION

Our results suggest a large heterogeneity in terms of PBMA’s acid-based impact, and reiterate that not all PBMA are created equal. PRAL values varied substantially across foods, and differences were as large as 19.73 mEq/100 g. In comparison to their MBEs, some mycoprotein-based PBMA were more acidic. The majority of foods, however, was more alkaline when compared to beef and pork.

PBMA were designed to mimic the nutritional profile of MBEs [2, 3]. Inherent to their purpose, they are processed foods with a moderate-to-high protein content. Thus, a positive PRAL value is naturally to be expected. Yet, differences in PRAL-relevant micronutrients could play a pivotal role. One example is potassium, which appears to be more abundant in PBMA [7].

At the same time, some PBMA also contain more phosphorus [7], which contributes to their acidity [9].

High-PRAL diets are associated with cardiovascular and kidney disease [1]. Selecting low-PRAL foods may thus be important for some individuals. In the case of PBMA, this appears difficult, as labeling of mineral information on packaged food labeling is at the discretion of the manufacturer in the European Union [2]. Data on micronutrient content is often lacking, and our PRAL-table might thus be helpful for individuals who wish to adopt a more alkaline diet. The original PRAL tables by Remer and Manz were constructed before the emergence of PBMA, and thus do not contain this novel food group. Inherent to a secondary data analysis, however, we did not measure nutrient contents of the examined foods ourselves, and acknowledge that methods and/or validity may have deviated between the examined datasets.

Some evidence suggests that PBMA might have a healthier nutrient profile than MBEs [11]. While the PRAL value of most items might be slightly lower, it is not anywhere near the (negative) PRAL value of unprocessed high-protein plant foods (e.g., beans). While PBMA could offer a steppingstone in the transition away from meat to increased plant consumption, they might be unsuitable to substantially alkalinize an individual’s diet.

DATA AVAILABILITY

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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AUTHOR CONTRIBUTIONS

Conceptualization: MAS; Data curation: MAS; Formal analysis: MAS; Investigation: JH and MAS; Methodology: MAS; Project administration: JH, RH and MAS; Resources: RH and MAS; Software: MAS; Supervision: RH and MAS; Validation: JH, RH and MAS; Writing – original draft: MAS; Writing – review & editing: JH, RH and MAS.

FUNDING

The authors received no financial support / funding. Open Access funding enabled and organized by Projekt DEAL.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s41430-024-01434-8>.

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