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COMPARATIVE NUTRITIONAL QUALITY OF CONVENTIONAL AND VALUE-ADDED AGRICULTURAL FOOD PRODUCTS

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ABSTRACT

Value addition can improve the usability, shelf life, and market potential of agricultural foods, but its relationship with nutritional quality varies across products and processing conditions. This study compared the nutritional characteristics of conventional/minimally processed and value-added agricultural food products using a cross-sectional food composition dataset. The analysis included 9,168 products, comprising 7,063 conventional products classified as NOVA 1 and 2,105 value-added products classified as NOVA 3. Nutrient composition, health score, and Nutri-Score indicators were compared using non-parametric tests, chi-square analysis, and food-category-adjusted regression models. Value-added products had higher median sodium and calcium concentrations, whereas conventional products contained higher iron and vitamin C levels and achieved a higher median health score. Nutri-Score distributions differed significantly between groups, with grade E occurring more frequently among value-added products. After adjustment for food category, value-added status was positively associated with energy, protein, saturated fat, calcium, and Nutri-Score value, while negative associations were observed for health score and sugar. Fiber, sodium, iron, and vitamin C showed no significant adjusted associations. The findings demonstrate that value addition produces nutrient-specific changes rather than a uniform improvement or deterioration in nutritional quality. Nutrient composition, food category, and processing intensity should therefore be considered jointly when developing and evaluating value-added agricultural foods.

Keywords: Agricultural foods, Value addition, Nutritional quality, Food processing, NOVA classification

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1.Introduction

However, food and nutrition security is not only dependent on volume of agriculture production, but also on the nutritional quality, accessibility, stability and diversity of the food that reaches consumers. Modern food systems are thus challenged with the task of ensuring sufficient food production as well as providing diets to support long-term health. In recent years, making food systems more sustainable has focused on nutrition-sensitive agricultural production and strengthening links between the production, processing, distribution and consumption of food (Oluwole et al., 2023). A value chain lens also considers both nutrition and agricultural productivity and economic performance, and identifies opportunities for enhancing food and nutrition security along the pathway between farm and consumer, in this case (Fanzo et al., 2017).

The degrees of change that are done to the agricultural products before consumption vary. Value addition may include cleaning, grading, drying, fermentation, preservation, cooking, packaging or formulation of products in a convenient and marketable form while conventional foods may reach consumers in raw or minimally processed forms. Processing and preservation are especially significant when it comes to minimizing deterioration, prolonging shelf life, ensuring food availability and promoting commercialization (Amit et al., 2017). Value addition can also offer an economic opportunity for agricultural communities by transforming the locally produced commodities into commodities that can be utilized and have good market potential, as has been done for the underutilized fruits resources (Srivastava et al., 2017). The vegetable processing offers similar benefits in terms of diversification of products, reduction of post-harvest losses and better utilization of agricultural produce (Mudgal & Kumar, 2023).

The nutritional impacts of these changes are complicated. The concentration, stability, digestibility and bioavailability of nutrients may be influenced by processing, which may either lead to increased or decreased values, depending on the food matrix and the processing technique employed (Singh et al., 2023). Certain treatments may increase palatability, safety, nutrient preservation, or nutrient accessibility, and others might alter the ratio of fat, sugar, sodium, or dietary fiber and/or decrease heat-sensitive nutrients. Postharvest interventions can also have an impact on the quality of the product and its storage properties, showing how processing conditions can affect the properties of the foods offered to consumers (Mhaka, 2020). The same can be applied to agricultural crops (pummelo) which are underutilized but have important nutritional attributes that can help in the broader interest in diversified value and utilization of agricultural produce (Singh, 2022). The need to link agricultural resources with locally appropriate food systems is further highlighted with adaptation of crops to bolster local food production (Coombs, 2019).

To investigate these differences, one way of doing so is by classification based on the processing level. According to the NOVA framework, the foods are classified based on the type and degree of industrial processing and have been used to classify the traditional and native plant foods based on the intensity of processing (Jideani et al., 2022). Its growing use has led to an investigation into the relation between processing and diet quality, but it is still subject of debate in food science due to its conceptual and technological limitations (Petrus et al., 2021). A multidisciplinary approach to ultra-processed foods further suggests that considering the nutritional value of a food requires considering the food itself, as well as the technologies used in food processing (Capozzi et al., 2021).

This separation is significant in the case of value added agricultural foods. The classification by food groups alone may fail to recognise significant variation resulting from processing, formulation and modification of structure. Conventional food classifications in nutritional epidemiology have been proposed to be inadequate to reflect the health aspects of food processing, as Fardet et al. (2015) claimed. Meanwhile, the association between main food groups and mortality has been shown to be important, and the food group dimension is still an important aspect of nutrition assessment (Schwingshackl et al., 2017). The use of the processing status in combination with the food category and nutrient composition might then be more informative as a representation of nutritional quality.

In comparing results from different agricultural commodities, there is still a need to ascertain whether value addition is related to consistent nutritional changes or whether the impact of value addition differs by nutrient and commodity types. The present analysis thus links conventional/minimally processed agricultural products with value added ones, regarding the main food categories, based on nutrient composition indicators, health score, and Nutri-Score. The aims were to:

- Compare nutrient profiles between conventional and value-added foods.
- Evaluate differences in overall nutritional quality between processing groups.
- Determine nutritional differences after accounting for food category.

2. Materials and Methods

2.1 Study Design and Data Preparation

In order to examine the nutrition differences between agricultural food products (conventional and value-added), a quantitative cross sectional comparative design was used (Amira, 2023). The analytical data set was checked for duplicate observations, missing observations, inconsistent observations and variables relevant to the nutritional assessment. Agricultural products in both processing groups were kept to allow for similar analyses. The number of products in the final analytical sample was 9,168 (corresponding to the Results section below).

2.2 Classification of Food Products

The food products were categorized based on the NOVA food processing system. NOVA 1 foods have been operationally defined as conventional or unprocessed, or minimally processed agricultural products, while NOVA 3 foods as processed value-added products. Dairy, meat, fruits, vegetables, seafood, grains, spices and herbs, and nuts and seeds were analyzed. This classification allowed for comparison of the nutritional characteristics between agricultural commodity groups in a consistent way, but with enough variation to be meaningful.

2.3 Nutritional Variables

The nutritional quality was evaluated based on energy, protein, total fat, saturated fat, fibre, sugars, sodium, calcium, iron, vitamin C, health score and Nutri-Score. For nutrients available, a standardized value per 100 g was used. The general nutritional indicators, health score and Nutri-Score, were maintained. All these factors directly related to the nutritional outcomes to which the comparative and adjusted analyses were applied.

2.4 Statistical Analysis

Python was used for data-management and statistical libraries to perform the statistical analysis. Distributional heterogeneity prevented the use of the mean and standard deviation for continuous nutrition variables; instead, median and interquartile range were used. The comparison between conventional and value added products was performed by the Mann–Whitney U test and the comparison of distributions of Nutri-Score grade by chi-square test. Multiple comparison adjustment was done using the Benjamini–Hochberg false-discovery-rate procedure. Furthermore, food-category adjusted regression models with HC3 heteroskedasticity-robust standard errors were estimated to obtain standardized differences between processing groups. All of the β coefficients were adjusted and presented with 95% confidence intervals and statistical significance was set at $p < 0.05$.

3. Results

The final analytical sample included 9,168 agricultural food products, comprising 7,063 (77.0%) conventional/minimally processed products (NOVA 1) and 2,105 (23.0%) value-added processed products (NOVA 3).

3.1 Distribution of Agricultural Food Products

Table 1 illustrates the difference in the representation of conventional and value added foods in eight agriculture categories. The meat segment was the biggest within conventional products (35.3%), while dairy products were the biggest in value added products (31.6%). Fruits were very well represented in both the groups, and nuts and seeds were found to be the lowest in the two groups.

Table 1. Distribution of conventional and value-added agricultural food products

Food category	Conventional, n (%)	Value-added, n (%)	Total, n
Dairy	848 (12.0)	665 (31.6)	1,513
Meat	2,493 (35.3)	215 (10.2)	2,708
Fruits	1,440 (20.4)	412 (19.6)	1,852
Vegetables	983 (13.9)	212 (10.1)	1,195
Seafood	482 (6.8)	324 (15.4)	806
Grains	618 (8.7)	230 (10.9)	848
Spices & herbs	170 (2.4)	37 (1.8)	207
Nuts & seeds	29 (0.4)	10 (0.5)	39
Total	7,063 (100.0)	2,105 (100.0)	9,168

As seen in Fig. 1, the conventional products were more prevalent in meat, fruits and vegetables and value added products were more prevalent in dairy and seafood.

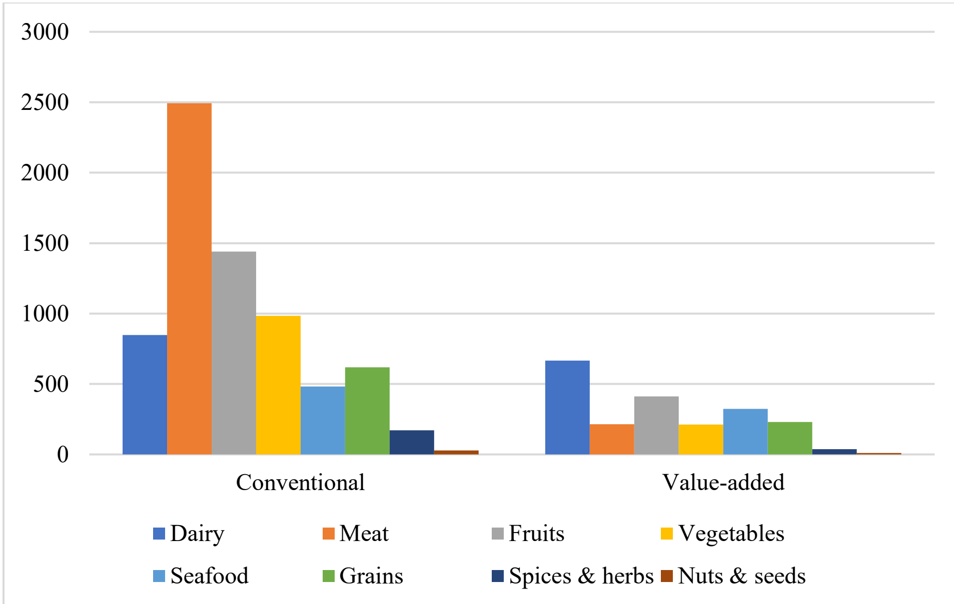

Figure 1. Distribution of conventional and value-added products across major agricultural food categories

3.2 Comparative Nutritional Composition

As can be seen in Table 2, there are significant differences in nutrition between the two groups. Value-added products had higher median sodium (76 vs. 54 mg/100 g) and calcium (31 vs. 17 mg/100 g), whereas conventional products contained more iron (1.05 vs. 0.36 mg/100 g) and vitamin C (0.30 vs. 0.00 mg/100 g). The Median health score of conventional foods was also greater than conventional foods (55 vs 50). There were no significant differences in energy, protein, carbohydrate, total fat or fiber (after multiple-testing).

Table 2. Nutritional composition of conventional and value-added agricultural food products

Variable	**Conventional, median (IQR)**	**Value-added, median (IQR)**	**Adjusted p**
Energy (kcal/100 g)	136 (50–272.5)	115 (55–322.7)	0.561
Protein (g/100 g)	8.87 (1.70–20.80)	8.93 (1.74–20.00)	0.534
Total fat (g/100 g)	1.98 (0.20–7.37)	1.34 (0–15.20)	0.366
Fiber (g/100 g)	0 (0–1.90)	0 (0–1.70)	0.173
Sodium (mg/100 g)	54 (10–74)	76 (12.75–406)	<0.001

Calcium (mg/100 g)	17 (8–48)	31 (8–132)	<0.001
Iron (mg/100 g)	1.05 (0.30–2.20)	0.36 (0–1.16)	<0.001
Vitamin C (mg/100 g)	0.30 (0–11.10)	0 (0–4.20)	<0.001
Health score	55 (50–60)	50 (50–60)	<0.001

There are significant differences in Nutri-Score grade distribution ($\chi^2 = 330.04$, $p < 0.001$) as shown in figure 2. Value-added products had a higher frequency of grade E (20.9%) compared to conventional products (8.1%), while grade A had a similar frequency in both.

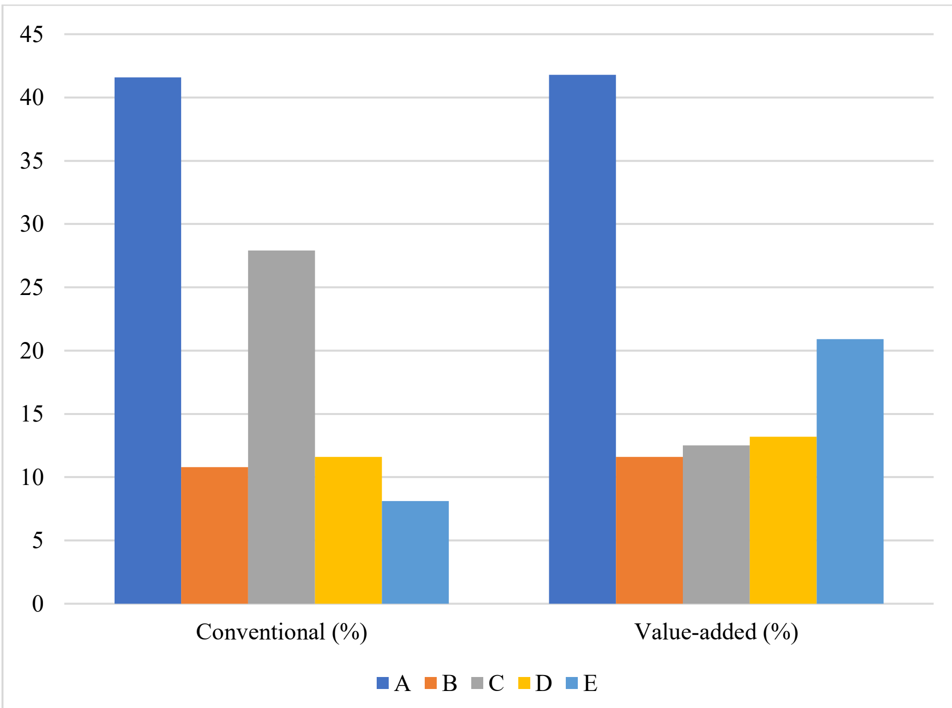

Figure 2. Distribution of Nutri-Score grades among conventional and value-added agricultural food products

3.3 Adjusted Nutritional Differences

Analysis by food category (after adjustment for commodity type) revealed that a number of differences were still present. Table 3 shows that value-added status was positively associated with saturated fat (β = 0.604), calcium (β = 0.433), Nutri-Score value (β = 0.415), protein (β = 0.227), and energy (β = 0.093). On the other hand, value added products showed a significantly lower health score (β = −0.409) and sugar level (β = −0.174). There was no significant adjusted association with fiber, sodium, iron or vitamin C.

Table 3. Food-category-adjusted associations between value-added status and nutritional outcomes

Outcome	Adjusted β	95% CI	Adjusted p
Energy	0.093	0.055 to 0.131	<0.001
Protein	0.227	0.190 to 0.264	<0.001
Saturated fat	0.604	0.551 to 0.658	<0.001
Fiber	−0.013	−0.064 to 0.038	0.618
Sugar	−0.174	−0.221 to −0.127	<0.001
Sodium	0.040	−0.037 to 0.117	0.380
Calcium	0.433	0.375 to 0.491	<0.001
Iron	0.056	−0.064 to 0.177	0.394
Vitamin C	−0.020	−0.055 to 0.016	0.377
Health score	−0.409	−0.456 to −0.362	<0.001
Nutri-Score value	0.415	0.357 to 0.474	<0.001

As seen in Figure 3, saturated fat was the strongest positive association with value-added status and health score the strongest negative association. In general, there was a unique shift in the nutritional composition and an unfavorable aggregate nutritional-quality profile (after taking into account the food category) of the value-added foods.

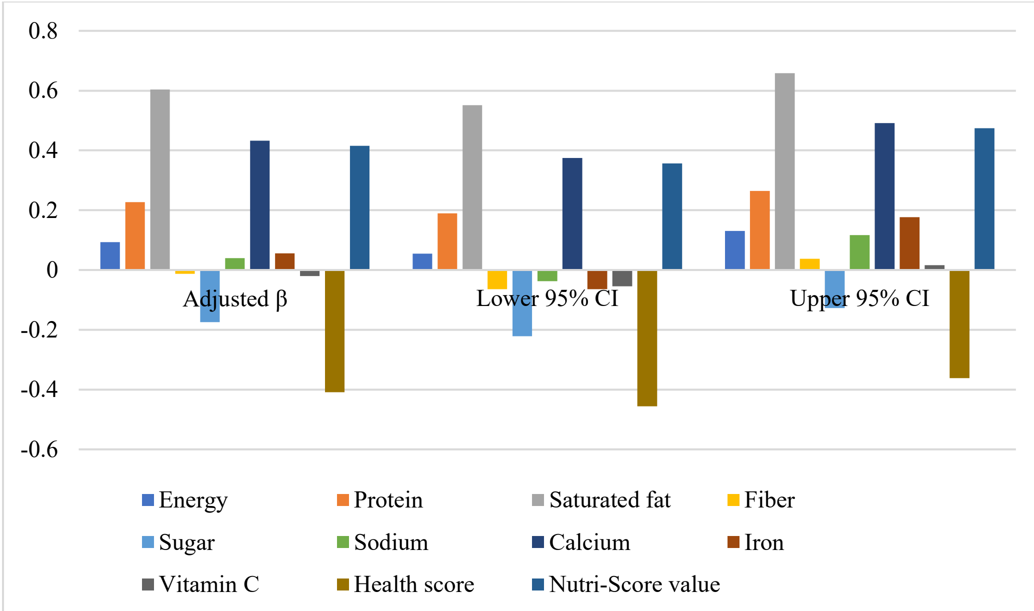

Figure 3. Food-category-adjusted standardized nutritional differences between value-added and conventional agricultural food products

4. Discussion

The nutritional comparison showed a variable trend, and not a consistent benefit for either processing group. In the conventional products, the median health score was better, and there was less in the Nutri-Score grade E, while value added products had a higher concentration of sodium and calcium in the unadjusted analysis. Food categories did not affect the value-added status as regards its association with energy, protein, saturated fat, calcium, Nutri-Score value and health score. These data confirm the conclusion that food processing is not just good or bad for the nutritional quality of foods, but that there are different food processing technologies with different aims and impacts on the composition of the food (Knorr & Watzke, 2019).

Variations in individual nutrients also illustrate the importance of using multiple dimensions of composition to assess nutritional quality. While macronutrients are primarily used to give information about the amount of energy and the amount of nutrients supplied by the food and diet, they are also important for accurate quantification when foods and diets are compared (Siebelink et al., 2015). The increase in protein in the value-added products is therefore a measure of one aspect of nutrition change, rather than of the quality of the products as a whole. Further, there are macronutrient and fibre interactions and individual metabolic factors that can affect dietary responses, which limits interpretability of responses to individual nutrients (Hjorth et al., 2019). It is, therefore, crucial to take a whole-food approach as foods, nutrients and dietary patterns are interdependent and affect overall diet quality (Tapsell et al., 2016).

Of particular interest are the higher level of saturated-fat in the value-added products and the less favorable aggregate nutrition-quality indicators. Meanwhile, the reduced adjusted sugar estimate shows there did not necessarily follow a rise in all of the nutrients that are typically considered undesirable. Such heterogeneity helps to explain some nutritional characteristics as sometimes it is not directly related to the intensity of the process, but to the formulation (Botelho et al., 2018). Recent criticism of NOVA also points out that not all ultra-processed foods should be considered nutritionally equivalent, and that there is a great deal of variation within the classifications of ultra-processing (Louie, 2025). The present findings thus argue for interpretation of nutrient-specific categories, and do not support the use of a single classification measure.

These differences in Nutri-Score results could also be relevant for nutrition information for consumers. There was a much higher incidence of value added products in grade E, but the percentage of grade A in the two groups was almost the same. Food-purchasing behaviour may be impacted by food-label policies when it is easy for consumers to access the nutrition information in the label, as seen after the implementation of the Chilean food labelling and marketing regulations (Taillie et al., 2021). These can be especially important if value-added products within the same agriculture commodity group vary significantly in nutritional content.

The nutritional value is just one part of how an agriculture and food system performs. The food processing can enhance food preservation, accessibility, convenience and safety, and poor food handling and market conditions can pose significant public-health risks (Gizaw, 2019). There is also significant variation in the environmental footprint of agricultural production and of food choice and, in principle, nutritional comparison should ultimately be made in parallel with resource use and sustainability outcomes (Clark & Tilman, 2017). Including nutrition in the product development and decision making process across supply chains can bring value-chain opportunities for improved market value as well as improved nutritional outcomes (Allen & De Brauw, 2018).

There are a few caveats to be taken into account. Processing classification was used as a proxy for adding value and not necessarily a specific processing technology, formulation or economic value generated. Some nutrients also had missing observations and the cross-sectional design does not allow for causal effects of processing to be determined. Future studies should compare equivalent raw and value-added products, include information about ingredients and methods of production, and include nutritional, economic and environmental outcomes. In general, results suggest that value addition has the ability to selectively modify nutritional profiles and that the food category, food formulation, food processing intensity and particular nutrients are important factors to consider when assessing the quality of the product.

5. Conclusion

Comparative assessment showed that there were not uniform but selective changes in the nutritional quality of agricultural foods associated with value addition. Conventional products were higher in median health score and in the unadjusted comparison, value-added foods had higher levels of sodium and calcium, and a lower proportion of Nutri-Score grade E products. Value added status had a positive association with energy, protein, saturated fat, calcium, and Nutri-Score value, while a negative association with health score and sugar were observed after adjusting for food category. Adjusted fibre, sodium, iron, and vitamin C concentrations were not significantly different. These results suggest that value addition cannot be presumed to have an inherently positive or negative impact on nutritional quality and that the impacts are different for different nutrients and types of products. Nutritionally responsible value addition should thus focus on minimizing the impact on the compositional change of the product, especially the increase in saturated fat, and reducing undesirable changes in the nutritional quality scores, while preserving beneficial nutrients. Future studies with the same raw and processed products, and further details about the processing methods and at the level of the ingredients, may shed light on the impact of specific value addition practices on nutrition and help to develop healthier agricultural food products.

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