Dietética e promoção da alimentação adequada e saudável
DOI: 10.12957/demetra.2025.82032

DEMETRA
Alimentação, Nutrição & Saúde
e-ISSN:2238-913X

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Using conversion indicator in blanched and thawed vegetables: an analysis of physicochemical parameters

Uso do indicador de conversão em vegetais branqueados e descongelados: uma análise dos parâmetros físico-químicos

Abstract

Introduction: Yield factor (YF) has wide application in food preparation and contributes to purchase planning, standardization of products/preparations, yield analysis, and waste reduction. However, the use of YF in blanched and thawed vegetables has still not been explored. *Objective*: To evaluate the YF of blanched and thawed fruits and vegetables and the impact of such processes on physicochemical parameters. *Method*: Samples of banana, potato, apple and carrot were minimally processed using blanching in immersion or steam, freezing and thawing steps. YF was calculated by the proportion of weight between blanched or thawed and edible portions. Physicochemical parameters such as total soluble solids, pH and acidity were evaluated during the processing. The results were evaluated using non parametric statistical tests with a significance level of 5%. *Results*: YF values were predominantly less than 1.0 due to the loss of moisture in the samples. At least for apples, immersion blanching resulted in greater solute losses. Still, it prevented an increase in acidity, probably by inhibiting the reactions that trigger enzymatic browning. *Conclusion*: Blanching and thawing modified the mass and physicochemical parameters of the foods studied. Therefore, the YF values found will contribute to better management in food processing establishments.

Keywords: Cooking conversion factor. Fruits. Vegetables. Food waste. Blanching. Thawing.

Resumo

Introdução: O indicador de conversão (IC) possui ampla aplicação no preparo de alimentos, contribuindo para o planejamento de compras, padronização de preparações, análise de rendimento e redução de desperdícios. No entanto, o uso do IC em vegetais branqueados e descongelados ainda é pouco explorado. *Objetivo*: Avaliar o IC de frutas e hortaliças branqueadas e descongeladas e o impacto de tais processos em parâmetros físico-químicos. *Método*: Amostras de banana, batata inglesa, maçã e cenoura foram minimamente processadas, utilizando etapas de branqueamento em imersão ou vapor, congelamento e descongelamento. O IC foi calculado pela relação entre a massa do alimento branqueado e/ou descongelado e a massa do alimento pré-preparado. Parâmetros físico-químicos, como sólidos solúveis totais, pH e acidez foram avaliados durante o processamento. Os resultados foram avaliados por estatística não paramétrica com nível de significância de 5%. *Resultados*: Os valores de IC calculados foram, predominantemente, menores que 1, demonstrando perda de umidade nas amostras. Ao menos para a maçã, o branqueamento por imersão proporcionou maiores perdas de solutos, mas evitou o aumento da acidez, provavelmente pela inibição das reações que desencadeiam o escurecimento enzimático. *Conclusão*: O branqueamento e o descongelamento modificaram a massa e parâmetros físico-químicos dos alimentos estudados. Portanto, os valores de IC obtidos contribuirão para uma melhor gestão em estabelecimentos processadores de alimentos.

Palavras-chave: Indicador de conversão. Frutas. Hortaliças. Desperdício de alimentos. Branqueamento. Descongelamento.

INTRODUCTION

Culinary indicators are important parameters that assist in the accurate forecasting of inputs and reduction of waste. These indicators are generated during the food preparation. The edible portion coefficient (EPC) is one such indicator. The EPC relates the as-purchase weight of the food toits edible portion weight.[1,2] By accounting for the removal of parts typically not consumed from certain foods, the EPC has been widely used to aid in waste control and production cost management in food processing/industrial establishments.[3-6]

The yield factor (YF) also known as the cooking conversion factor (CCF), or the conversion factor (CF), is another culinary indicator. The YF relates the yield to the edible portion weight of the foods and, therefore, indicates changes in the food during preparation, including, primarily, prolonged cooking.[1,2,6,7] The YF is still relatively under-researched in waste control, possibly due to its involvement with moisture loss and the absortion of moisture or oil by the food during cooking, rather than more visible losses as seen with the EPC. However, it is known that the YF is associated with preparation yield and, if not used in planning, can result in either a shortage or excess of inputs, leading to the latter case of waste.[8]

According to Philippi,[2] the YF can reflect physical, chemical, and biological changes to which foods are subjected during processing, allowing its application to foods that do not necessarily undergo prolonged cooking. Thus, two plausible scenarios where the YF could be employed, and which are under-studied, are blanching and thawing of foods. In blanching, enzymes that could alter food texture are inactivated, preventing excessive softening and water loss after thawing.[9,10] In freezing, foods suffer tissue damage from ice crystals formed, and with subsequent thawing, may lose mass due to water fusion processes and cellular exudate leakage.[9,11] These processes are widely used in the minimally processed frozen food industry, such as frozen fruits or vegetables, and are easily applied at the domestic level. These foods provide greater convenience for both consumers and food services, reducing the time for pre-preparation and, consequently, the preparation time of those foods and/or meals.[12]

Fruits and vegetables are perishable foods widely used in food processing/industrial establishments with higher waste rates throughout the production chain, according to the Center for Strategic Studies and Debates.[13] Therefore, strategies that could contribute to one of the United Nations Sustainable Development Goals related to responsible consumption and production, aiming to reduce food waste by 50% by 2030,[14] are of extreme relevance.

Another measure related to food thawing, but aimed at monitoring the water addition process in poultry carcasses and cuts and fish glazing, is the thawing percentage. This relative measure links the volume of thawing to the weight of the frozen food, with limits set at 8% during chicken thawing and 12% for fish[15,16]. Although not intended for regulatory purposes, thawing indicators for fruits and vegetables are also scarce in the literature.

It has been demonstrated that both blanching and thawing can cause changes in food mass.[17] In this regard, the aim of the present study was to quantify mass variation during the processing of blanched and thawed fruits and vegetables, in order to establish YF values. Additionally, the effect of these processes on physicochemical parameters was evaluated.

METHOD

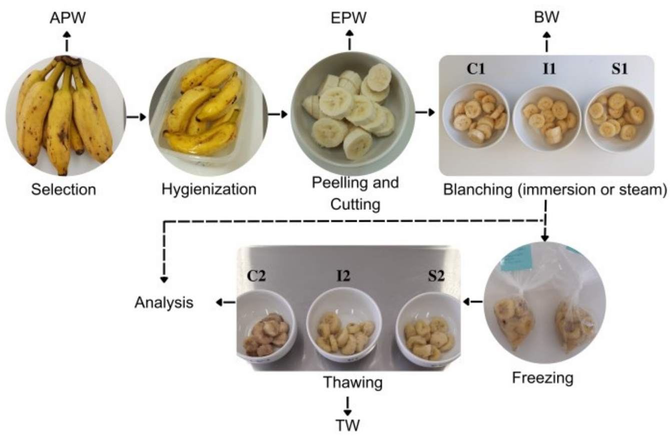
This is a quantitative and experimental research in which samples of "Prata" banana(Musa acuminata *x Musa balbisiana*), potato (*Solanum tuberosum*L.), "Fuji" apple (*Malus domestica* Borkh) and carrot (*Daucus carota*

L.) were processed, as described by Silva.[18] The vegetables were selected, according to typical quality characteristics,[19,20] in local supermarkets, taken to the laboratory and analyzed on the same day. The vegetables were then washed in running water, sanitized in a 150 ppm chlorinated solution for 15 minutes and rinsed. They were then peeled and divided into appropriate formats.

Portions of approximately 100 g for banana and potato and 200 g for carrot and apple were divided into the following experimental groups: samples only blanched (treatment 1), which include samples blanched in immersion (I1) and steam (S1); and blanched and frozen/thawed samples (treatment 2), which include immersion-blanched and frozen/thawed (I2) and steam-blanched and frozen/thawed (S2) samples. Two control groups were used during the experiment: control 1 (C1), in which the samples were only pre-prepared; and control 2 (C2), in which the samples were pre-prepared and frozen/thawed. In both controls, the blanching step was omitted.

The samples were blanched by immersion and steam at 100°C, respectively, using the following times: banana - 1 and 2 minutes; potato - both 3 minutes; apple and carrot - 3 and 2 minutes. Samples were frozen for 30 days. Slow processes were applied during freezing and thawing (Figure 1).

Figure 1. Generic production flowchart for fruits/vegetables.The figure highlights the sequential weighting and when the physicochemical analyses were carried out (APW: as-purchased weight; EPW: edible portion weight; BW: blanched weight; TW: thawed weight; C1: blanched control sample; I1: immersion-blanched sample; S1: steam-blanched sample; C2: thawed control sample; I2: immersion-blanched and thawed sample; S2: steam-blanched and thawed sample).



The mass of the samples was measured throughout processing on a semi-analytical scale (MARTE, AD330, Brazil) and the conversion indicator was calculated using the formula $CCF = \frac{PFW}{EPW}$, where PFW and EPW correspond to the processed food weight (after blanching and/or thawing) and edible portion weight, respectively.

The pH, titratable acidity (TA) and total soluble solids (TSS) were measured according to the Adolfo Lutz Institute methodology,[21] before and after thawing. The pH was determined by the electrometric process with a pH meter (KASVI, K39-1410A, Brazil). Total soluble solids were measured using a bench refractometer (ADUTEC, EEQ 9001, Brazil), with a graduated brix scale and temperature correction table.

Acidity was obtained by titration with 0.01 molar sodium hydroxide solution standardized with potassium biphthalate and phenolphthalein indicator. The association with the potentiometric method was made in colored samples and in those that darkened after processing. The formula used was: $g\ of\ organic\ acid\ percent\ w/w\ or\ w/v = \frac{VxFxMxMW}{10xWxn}$,where V = volume of sodium hydroxide solution used in the titration in mL; F = correction factor for sodium hydroxide solution; M = molarity of the sodium hydroxide solution; MW = molecular weight of the corresponding acid in g; W = mass of the sample in g or pipetted volume in mL; n = number of ionizable hydrogens. The predominant acids considered were citric, in potatoes and carrots, and malic, in apples and bananas.

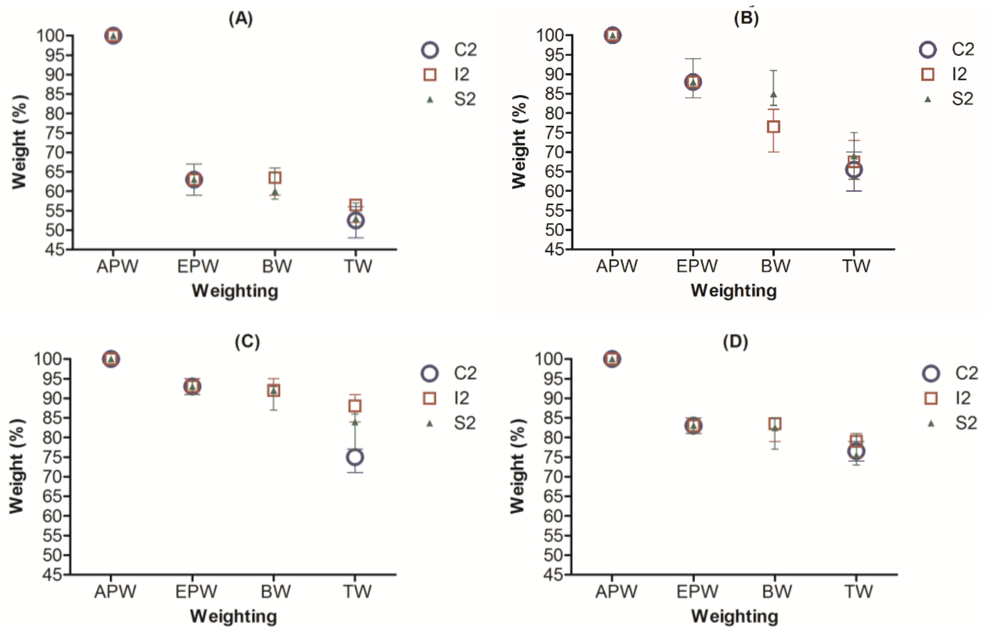
The ratio or ripening index was calculated for fresh samples, according to the following formula: $Ratio = \frac{TSS}{TA}$, where TSS is the total soluble solids content and TA is the titratable acidity.

After applying the Shapiro-Wilk normality test to evaluate the homogeneity of variances and residuals, with the help of IBM® SPSS® software version 26.0 and GraphPad Prism version 5.01, nonparametric statistical tests were chosen at a significance level of 5%. The Wilcoxon test was applied to evaluate the CI variation in samples that were only blanched. The repeated-measures Friedman test, followed by Dunn's post-test, was used to compare the CI after thawing, and also the simultaneous effect of blanching and thawing on the physicochemical parameters of the vegetables

RESULTS

To calculate the YF, sequential weighing of the foods was carried out, and the greatest loss of mass at the end of processing. Specifically, after the thawing stage – was observed for bananas (at least 43%), followed by apples, carrots and potato. Except for carrots, greater moisture loss was observed in the control treatment. Comparing the mass loss between blanching and thawing alone, the greatest loss was observed for apples (at least 9%) (Figure 2).

Figure 2. Evolution of vegetable weight throughout processing. (A) Banana; (B) Apple; (C) Potato; (D) Carrot. APW: as-purchased weight; EPW: edible portion weight; BW:blanched weight; TW: thawed weight; C2: Thawed control samples; I2: immersion-blanching thawed samples; S2: steam-blanched thawed samples. The experiment was repeated six times. Each data point corresponding to the median of six independent experiments, and the bars, to the range values.



The YF distribution of steam-blanched (S1) or immersion-blanched (I1) samples was considered similar in the carrot sample ($p > 0.05$). In banana and potato, immersion blanching generated higher YF values ($p < 0.05$). In apples, the opposite was observed (Table 1).

Table 1.Yield Factor (YF) obtained after blanching the fruits/vegetables. Macaé-RJ, 2024.

Fruit/ vegetable	Sample	YF			
		Median	Minimum	Maximum	Range
Banana	I1	1,005[a]	0,954	1,037	0,083
	S1	0,990[b]	0,939	1,150	0,211
Apple	I1	0,856[b]	0,823	0,870	0,047
	S1	0,951[a]	0,930	1,008	0,078
Potato	I1	0,998[a]	0,969	1,001	0,032
	S1	0,983[b]	0,957	0,995	0,038
Carrot	I1	0,996[a]	0,981	1,019	0,038
	S1	0,993[a]	0,959	1,011	0,052

Different letters denote significant difference (Wilcoxon, two-tailed; $p < 0.05$). I1: immersion-blanched samples; S1:steam-blanched samples. The experiment was repeated six times.

The YF distribution of thawed samples was considered similar ($p > 0.05$) in bananas and apples (Table 2), regardless of whether the blanching step was carried out. It was also observed that immersion blanching (I2) reduced the loss of liquids after thawing potatoes and carrots and generated higher YF values than the control sample (C1). This demonstrates that, at least immersion blanching, was able to preserve the weight of both vegetables, reducing losses and increasing yield

Table 2.Yield Factor (YF) obtained after thawing the fruits/vegetables. Macaé-RJ, 2024.

Fruit/ vegetable	Sample	YF			
		Median	Minimum	Maximum	Range
Banana	C2	0,833[a]	0,766	0,940	0,174
	I2	0,872[a]	0,833	0,953	0,12
	S2	0,866[a]	0,814	0,908	0,094
Apple	C2	0,745[a]	0,680	0,781	0,101
	I2	0,848[a]	0,730	0,904	0,174
	S2	0,782[a]	0,741	0,841	0,100
Potato	C2	0,803[b]	0,770	0,848	0,078
	I2	0,936[a]	0,926	0,990	0,064
	S2	0,901[ab]	0,882	0,937	0,055
Carrot	C2	0,918[b]	0,901	0,954	0,053
	I2	0,943[a]	0,927	0,972	0,045
	S2	0,907[b]	0,901	0,966	0,065

Different letters denote significant difference (Friedman; $p < 0.05$; Dunn; $p < 0.05$). C2: thawed control samples; I2: immersion-blanched and thawed samples; S2: steam-blanched and thawed samples. The experiment was repeated six times.

Table 3 shows the simultaneous effect of blanching and thawing on the physicochemical parameters of the vegetables studied. When comparing the pre-prepared vegetable samples (C1) with the immersion-blanched and thawed samples (I2), in the apple there was a slight loss of total soluble solids and an increase in pH, with a significant reduction in titratable acidity ($p < 0 .05$). In bananas, there was a reduction in pH ($p < 0.05$), however without a significant change in titratable acidity.

Table 3. Simultaneous effect of blanching and thawing on the physicochemical parameters of the fruit/vegetable. Macaé-RJ, 2024.

Fruit/ vegetable	Sample	Total Soluble Solids(ºBrix)				pH				Titratable acidity (%)			
		Med	Min	Max	Range	Med	Min	Max	Range	Med	Min	Max	Range
Banana	C1	23,50[a]	19,83	27,66	7,83	4,76[a]	4,42	4,94	0,52	0,50[a]	0,43	0,51	0,08
	I2	21,88[a]	21,34	22,83	1,49	4,64[ab]	4,32	4,83	0,51	0,49[a]	0,41	0,52	0,11
	V2	24,12[a]	23,08	24,77	1,69	4,60[b]	4,32	4,75	0,43	0,61[a]	0,45	0,71	0,26
Apple	C1	9,71[a]	8,58	22,49	13,91	3,85[b]	3,59	4,00	0,41	0,21[a]	0,17	0,34	0,17
	I2	7,92[b]	7,24	8,42	1,18	3,98[a]	3,68	4,15	0,47	0,150[b]	0,12	0,23	0,11
	V2	8,58[ab]	8,16	10,24	2,08	3,90[ab]	3,69	4,00	0,31	0,175[ab]	0,14	0,30	0,16
Potato	C1	3,03[a]	1,29	3,82	2,53	6,34[a]	6,03	6,53	0,5	0,13[a]	0,09	0,16	0,07
	I2	2,25[a]	1,50	2,57	1,07	6,11[a]	5,65	6,31	0,66	0,13[a]	0,12	0,14	0,02
	V2	2,66[a]	2,25	4,42	2,17	6,17[a]	6,03	6,29	0,26	0,15[a]	0,13	0,22	0,09
Carrot	C1	7,99[a]	6,16	9,24	3,08	6,12[a]	5,96	6,23	0,27	0,06[a]	0,02	0,09	0,07
	I2	6,00[a]	5,25	6,41	1,16	5,92[a]	5,47	6,15	0,68	0,06[a]	0,06	0,09	0,03
	V2	5,96[a]	5,75	6,91	1,16	5,97[a]	5,67	6,15	0,48	0,07[a]	0,06	0,07	0,01

Different lowercase letters denote a significant difference between samples of the same fruit/vegetable (Friedman: $p < 0.05$; Dunn: $p < 0.05$). C1: blanched control samples (only pre-prepared samples); I2: immersion-blanched and thawed samples; V2: steam-blanchedthawing samples; Med: median; Min: minimum; Max: maximum. The experiment was repeated six times.

Another factor evaluated in the study was the ratio or ripening index, with maximum and minimum values of 39 and 62, respectively, being found for bananas. For potatoes, these values were 12 and 26. In relation to apples, the values were 31, maximum, and 53, minimum. And for carrots, these values were 74 and 318, respectively.

DISCUSSION

In the present study, more significant variations in the YF of thawed samples were identified. Even though the YF values come to 1.0, a small variation in mass in samples that have only been blanched, it is important to consider that, when it comes to planning and production costs, small variations already impact the budget.[12] Therefore, considering that the YF generally reflects changes in mass arising from prolonged cooking processes, the present work brings an innovative proposal to determine YF values applicable to the minimum processing of vegetables in which the blanching and thawing steps are used. These steps can be easily adopted to preserve food at the household level.

The Menu planning (MP) is a management instrument commonly used in the operational control of menus in food services.[22] The main culinary indicators presented in the MP are the EPC and the YF.[23] While the first may indicate loss of peel, seeds and trimmings during pre-preparation,[1,2] the second indicates loss or gain of moisture or oil absorption[8] during preparation. Several studies have already demonstrated a successful application of these indicators to better manage costs and food waste.[3-5] Although the use of YF during blanching and thawing is still little explored in the literature, making comparisons with previous studies somewhat limited, our results allow us to verify a greater variation in mass in the pre-preparation stage of vegetables, a fact that reinforces the applicability of the EPC in waste management.

After thawing, a change in texture was noticed in the samples, especially in the control samples (data not shown). Oxidative processes arising from enzymatic browning in control samples, the effect of heat on blanched samples and the loss of water through dripping during defrosting are among the factors triggering the observed texture change. Previous work has also demonstrated changes in the texture of vegetables after the blanching and thawing stage.[24,25] Song, Na & Ki[24] observed that blanched (100°C/10 min) and thawed soybean seeds showed loss of soluble sugars due to leaching and alteration in the texture of processed soybeans. On the other hand, the change in the texture of the vegetable was considered positive from a sensorial point of view, since the greater softness of the blanched soybeans generated better sensorial acceptance among the tasters.

Therefore, the evaluation of the instrumental texture profile would be recommended for a more appropriate use of these foods in culinary preparations, in order to maintain their good acceptance. It is worth noting that the choice of vegetables studied was based on consumption data from the Pesquisa de Orçamentos Familiares (POF – Consumer Expenditure Survey)[26], in which the most consumed ones were selected.

The physicochemical analyzes allowed us to guide possible changes that occurred in the food as a reflection of the processing adopted. Such changes are closely related to the type of food matrix and its initial chemical constitution, which varies, among other factors, with climatic and cultivation conditions and the stage of maturation.[9]

Even though blanching is considered a mild heat treatment, this process generates destruction of plant cell membranes,[27] causing loss of selective permeability. In addition, the presence of starch in foods, through the gelatinization phenomenon, can reduce water permeability in plant tissue.[28,29]

Gelatinization is a complex process that involves the breaking of intermolecular bonds in the amylose and amylopectin molecules that form starch in the presence of water and heat. During this process, more water molecules are involved in sites containing hydrogen bonds.[28,29] Remarcably, the concentration of starch in vegetables is variable, being in higher concentrations in the initial stages of the maturation stage.[30]

In this case, the ratio or maturity index can be an important parameter to be considered, indicating that, as the food matures, there is an increase in the total soluble solids content and a reduction in acidity.[31] Furthermore, it indicates the harmony between sugars and acidity, it is being a desirable attribute among consumers.

In this sense, the results obtained in this study showed that, at least for bananas and apples, the ripening stage was not a major factor in the variation of the initial physicochemical parameters of these fruits. This is because the ratio values found for these fruits were in accordance with scientific studies by reflecting a more advanced stage of maturation and, therefore, lower starch content.[32-35]

Freezing, especially slow freezing, can largely influence the formation of ice crystals, cause vacuole rupture and damage to the cell wall structure of vegetables, resulting in loss of turgor pressure, expansion of the intercellular space and cell collapse. This process also leads to water loss during thawing, as bound water converts to immobilized and free water.[36] Furthermore, thawing also promotes retrogradation, a process resulting from the exudation of amylose from gelatinized starch granules. The amylose, outside from such structures, it is associated with chains that surround them, causing strong interaction with consequent water exit from these systems, characterizing syneresis.[37,38]

The information above, taken together, can help explain the variations observed in the YF and TSS values of the vegetables studied. For samples that were only blanched, specifically apples, steam blanching preserved the dough better. As for potatoes, perhaps the better thermal efficiency of immersion blanching may have positively influenced the gelatinization process of the starch still present in the vegetable and justify the lower water loss observed. Furthermore, it was possible to verify that the prior immersion blanching of potato and carrot samples was able to preserve the mass of these vegetables after thawing. This reinforces that blanching is a key process for freezing vegetables[39] and that there are particularities between types of blanching and the food matrix to obtain better YF values.

The association of blanching with freezing/thawing of samples resulted in loss of solutes in the immersion-blanched apple group (I2), when compared to the control group (C1), referring to only pre-prepared samples. This result is in line with the literature, indicating considerable loss of these components in apples[40] during processing. Previous blanching of vegetables also prevented an increase in acidity in apple samples blanched in immersion, because freezing alone is not capable of preventing enzymatic browning in vegetables with a high concentration of phenolic compounds.[41,42]

A strong point of our research was demonstrating that blanching and thawing, and not just prolonged cooking, cause changes in the characteristics of foods, resulting in changes in mass. This reinforces the practical applicability of the conversion indicator for planning inputs, costs and waste management in establishments that practice minimal vegetable processing. A relevant consideration is the need to determine culinary indicators, particularly the conversion indicator, in a wide range of blanched and/or defrosted vegetables using a standardized methodology, which could be supplied in future research..

CONCLUSION

The present work demonstrated that blanching and thawing are unitary processes that generate changes in mass and impacts on the physicochemical characteristics of minimally processed vegetables. Therefore, it is concluded that the YF values obtained for bananas, potatoes, apples and carrots, through a standardized methodology, can be adopted by the industry as theoretical reference values for forecasting supplies, production costs and waste control. As it is a pioneering study in the area, research with other vegetables should be carried out to promote greater reflection on the topic.

ACKNOWLEDGMENTS

To CAPES, for providing access to scientific publications. To FAPERJ, for the financial support (E-26/202.222/2021).

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Soares RM, Carvalho LL and Mata GMSC participation in conception and design, analysis and interpretation of data, review and approval of the final version; Leite AMOo participation in statistical analysis and data interpretation; review and approval of the final version.

Conflict of Interest: The authors declare that there is no conflict of interest.

Received: February 13, 2024
Accepted: July 17, 2024