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A domestic-like carrot cooking methodology for multiple research applications

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ABSTRACT

Domestic-oriented research focusing on food requires methodologies that closely mimic practices occurring in home kitchens while meeting scientific standards. Currently however, there is a lack of methodologies that can be implemented in both laboratory and home environments. This paper proposes a method that fulfills the scientific requirements of repeatability and reproducibility, while utilizing commonly available materials and processes found in the average household. The method is applied to the preparation, boiling, and seasoning of roots of *Daucus carota* L. ("carrots"), which can be employed in various scientific fields with only minor adjustments. Three scientific experiments utilizing this methodology are presented, namely sensory evaluation, ionic chromatography measurements, and NMR experiments. In the existing literature, numerous protocols have been used for carrot sample preparation, hindering direct comparisons between studies. In this paper we would like to highlight the ability of the methodology to enhance comparability, as well as its potential utilization in other research applications. The main principles underlying the proposed methodology can also be extrapolated to prepare samples of several other vegetables or cereals.

- Comprehensive guidelines for standardizing the shapes, lengths, and widths of carrots are outlined, ensuring minimal variability while preserving the integrity of the raw material.
- The cooking method for carrots is tailored to utilize commonly available household materials, while meeting scientific standards required for research purposes.
- Seasoning practices involving readily available domestic materials, like commercial salt, are suggested.

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Method details

Various carrot cooking protocols in the literature

When examining cooking methods employed in domestic settings, canteens, and catering kitchens, significant variations in processes become apparent. For example, one can consider the boiling of vegetables, where the water-to-food ratio can vary substantially. The challenge for the scientific community, when investigating practices resembling those at home, lies in achieving a balance between representing domestic routines faithfully while meticulously controlling, measuring, and replicating every step of the scientific protocol. Achieving this equilibrium is essential to generalize the results obtained on a global scale. Within the scientific literature, numerous studies focus on cooked carrots, with some aiming to replicate domestic practices. However, each study employs a distinct preparation methodology and cooking procedure, and these differences will be discussed in this first section.

De Belie et al. [1] used physico-chemical methods to assess changes in carrot texture and sweetness during cooking. This experiment was done to provide tools for the ready-to-use food products and catering industries to determine the "optimum cooking time" and for post-processing quality evaluation. To prepare the samples, carrots with a diameter of 25–30 mm were selected. Then, cylinders with a height of 8 mm and a diameter of 25 mm were taken from selected carrots (2 to 6 cylinders per carrot). The lower part (opposite the stem end) of the carrots was excluded because, according to the authors' internal results, this part differed the most from the rest of the carrots. The slices were then cooked in boiling water (undisclosed type, 100 °C) for up to 15 min.

Gayathri et al. [2] used a domestic cooking process to cook different vegetables including carrots. They evaluated the retention of beta-carotene during the different cooking processes. One of the domestic processes used was boiling in water (type not specified). Carrots were diced to a uniform size of 5 mm thickness. Then, they were boiled (m = 10 g) in an open vessel in the presence of water (80 mL initially) and 0.1 g of commercial salt for 10 min, stirring was performed at 2 min intervals. Experiments involving simulated gastrointestinal digestion were further performed.

Zhang and Sun. [3] investigated the effect of cooling methods on the cooling efficiencies and qualities of carrot slices. The goal of this experiment was to provide efficient strategies to achieve shorter cooling times for the ready-meal industry. Carrots were washed but not peeled. They were cut into slices with a thickness of approximately 5 mm, and a diameter of 25–45 mm, using a slicer. For cooking, 1.2 kg of carrot slices were added into a pot filled with 3 L of boiling water for 25 min. They analyzed the moisture content, color, texture, total viable count, vitamin C, and β-carotene content of the carrots.

Cazor et al. [4] analyzed metabolites (including sucrose, D-glucose, D-fructose, amino acids and organic acids) from aqueous extracts of slices of carrots after thermal processing in distilled water. Sample preparation was as follows: 0.5 cm sections from both ends of the carrots were removed to eliminate leaves and secondary roots. Then, the carrots were peeled and cut lengthwise into four parts. From those parts, disks sectors of a 5.5 mm thickness were cut. To cook the sectors, a 250 mL three necked glass flask was used. A condenser was used, so no water was lost during the cooking process. 30 g of prepared carrots were processed in 100 mL of hot water (50, 75, 100 °C). For this study, the maximum processing time was very high (up to 72 days). Proton nuclear magnetic resonance spectroscopy (^{1}H NMR) spectroscopy was performed to quantify the saccharides, amino acids and organic acids from the stocks [5].

Trejo Araya et al. [6] compared the sensory perception and quality attributes of carrots cooked through 3 different methodologies (high-pressure treatment, sous-vide cooking and cooking in boiling water (type non-specified) for 20 min at 100 °C). Carrot sticks were used as a model product. The carrots used were *Daucus carota L.*, var '*Stephano*'. Carrots were washed, peeled, and cut into beams (7 mm width, 7 mm height, 100 mm length) using a potato chip cutter. 500 g of carrot beams were then mixed, vacuum packed, and cooked. Heat treatments were performed using a temperature-controlled water bath. After processing, the cooked bags were immersed in ice water to promote rapid cooling. The main objective of this study was to evaluate the benefit of cooking food by high-pressure treatment compared to thermally/traditional processing of foods, highlighting the benefit in having well defined domestic cooking methodologies. A sensory evaluation was performed. Gas chromatography-mass spectrometry (GC/MS) and Gas chromatography-mass spectrometry-olfactometry (GC/MS-O) were also used for olfactory detection and description. Texture, juiciness, and color measurements were performed. Finally, cryo-scanning electron microscopy was used to observe the cellular microstructure of cooked carrots.

Aherne et al. [7] evaluated the bioavailability of beta-carotene from cooked carrots after consumption. Following their preparation protocol, carrots were peeled and sliced in a standardized way (but no details on the dimensions are provided). Then, carrots were boiled in 500 mL of water (type non-specified) for 6 min at a steady rolling boil. *In vitro* digestion model with a human intestinal cell model was then used to study the bioavailability of beta-carotene.

Lee et al. [8] studied the physical and functional properties of carrots (hardness, color, phenolic content, beta-carotene, and calcium content were analysed). The carrots were cut into fixed-sized cubes of 0.7 cm and then boiled in deionized water (100 g of carrots in 1 L) for 8, 14, or 23 min. Their objective was to compare different cooking methods on the physical and functional properties of carrots.

Table 1
Variations in carrot cooking methods across published scientific papers.

Article	Carrot shape	Time of cooking	Type of water	Carrot to water ratio	Type of process
De Belie et al. [1]	Cylinders (8 mm height, 25 mm diameter)	15 min maximum at 100 °C	Not specified	7 discs per L	Ready-to-use food product and catering industries process
Gayathri et al. [2]	Cubes (5 mm thick)	10 min at 100 °C	Not specified	125 g/L	Domestic process
Zhang and Sun [3]	Unpeeled slices (5 mm thick, 25–45 mm diameter)	25 min at 100 °C	Not specified	0.4 g/L	Ready-meal industry process
Cazor et al. [4]	Disk sectors (5.5 mm thickness)	Not relevant	Distilled water	300 g/L	Scientific process
Trejo Araya et al. [6]	Beams (7 mm width, 7 mm height, 100 mm length)	20 min at 100 °C	Not specified	Not specified	Domestic process
Aherne et al. [7]	Slices (unspecified dimensions)	6 min at 100 °C	Not specified	Not specified	Domestic process
Lee et al. [8]	Cubes (7 mm thick)	23 min maximum at 100 °C	Deionized water	100 g/L	Domestic process

All these papers deal with carrots cooked in boiling water (with other methods occasionally being used). Some differences are striking and prevent researchers from making proper comparisons among the results (Table 1). The most important difference is the variety of shapes that the carrot samples had depending on the study. Carrots were cut into sections [6], cubes [2,8], or cylinders [1,3,4,7]. In addition, the size was not always the same among the same shapes. For example, some cubes had a 0.7 cm thickness [8] while others had a 0.5 cm thickness [2,4]. Cylinders had different proportions, 5 mm * 25–45 mm (height * diameter) in the paper by Zhang and Sun. [3] or 8 mm * 25 mm (height * diameter) in the paper by De Belie et al. [1]. Another parameter that differs among studies is the type of water used for cooking. In fact, the type of water is often not reported, despite its potential influence on the interactions between the dissolved salts in the water and/or the food matrix, as well as its influence on the components during cooking. The cooking time is not uniform either, but this is likely due to the different shapes and volume of carrot samples. Some of these papers explicitly attempt to mimic domestic practices and are driven by consumers' interests and health concerns, but their protocols are often exclusive to their own studies and not adopted by other research teams.

Therefore, establishing a standardized method for preparing vegetables like carrots that also closely mimics common domestic processes appears to be highly beneficial. This is particularly significant given that a substantial amount of research on carrots is conducted for the benefit of consumers. The method proposed in this paper can serve this purpose and facilitate a better comparison of published results. The methodology described here uses domestic equipment that can be easily found at relatively low prices in supermarkets, enabling various scientific teams, including those from low-income countries, to utilize it.

Proposed methodology

Raw carrots preparation

Roots of *Daucus carota* L. ("carrots") were purchased from a local supermarket (Carrefour, Dijon, France) and stored at 4 °C which is the recommended temperature of domestic fridges. Carrots were bought 4 to 7 days after being harvested, then stored 1 to 7 days more before being processed. Storage at low temperatures decreases the process of respiration, the rate of transpiration and weight loss compared to storage at 10 °C, 15 °C and room temperature [9]. Fungal growth is also prevented [10]. Therefore, carrots physiological modifications are delayed. Still, storage time can have an influence on carrot characteristics. For example, the proportion of beta-Carotene isomers in raw carrots fluctuates during 60 days of storage [11]. Alasalvar et al. [12] found no differences regarding the total antioxidant activity in orange carrots during storage (13 days at 5 °C). However, they found a gradual decrease of total carotenoids and an increase of the total phenolic content. According to some studies objectives, storage time should be considered but was not a factor of interest for our methodology. From a consumer perspective, carrots can be stored for 2 to 3 weeks in the refrigerator (at temperatures between 0.5 °C and 4.5 °C) [13].

The selected carrots (Carottes Filière Qualité Carrefour, Origine Aquitaine) were cultivated in France in 2022 according to agroecological principles and following the so-called "Carrefour Quality Line". According to this "Quality Line", no synthetic insecticides were used after the seedlings' emergence. Choosing agroecological carrots should limit chemical interferences during analytical analyses (*e.g.*, pesticides). Using carrots sold in packages also reduces inter-vegetable differences in terms of provenance and harvesting dates. Moreover, the batch number indicated on the package label allows traceability and may contribute to the carrots sample homogeneity which is crucial in regard to scientific requirements.

After being peeled with a hand peeler (the peel thickness was less than 1 mm) (Fig. 1A), the top and the bottom of the carrot were cut to achieve a length of 10 cm. This length was used to be able to remove at least 1 cm from both extremities to eliminate leaves and secondary roots as is usually done in the home. By doing so, the parts that may differ the most from the rest of the carrots were excluded [1]. A length of 10 cm was also decided for practical reasons for sensory experiments conducted in our lab. A uniform carrot size was necessary to achieve a standardized protocol. Cutting was performed using a sharp knife lowering (but not preventing) cell permeability and level of exudate produced compared to cutting with a machine blade [14]. The diameters of the cut carrots ranged from 1.6 to 2.2 cm, a limit set for practical reasons. The smallest common diameter in the purchased package was around 2 cm. Choosing a relatively small size range aimed at achieving uniformity in peeled carrots. To obtain such a range, a pre-selection of carrots had to be done. Raw carrots from the purchased package with a maximal diameter superior to 2.5 cm or with a minimum

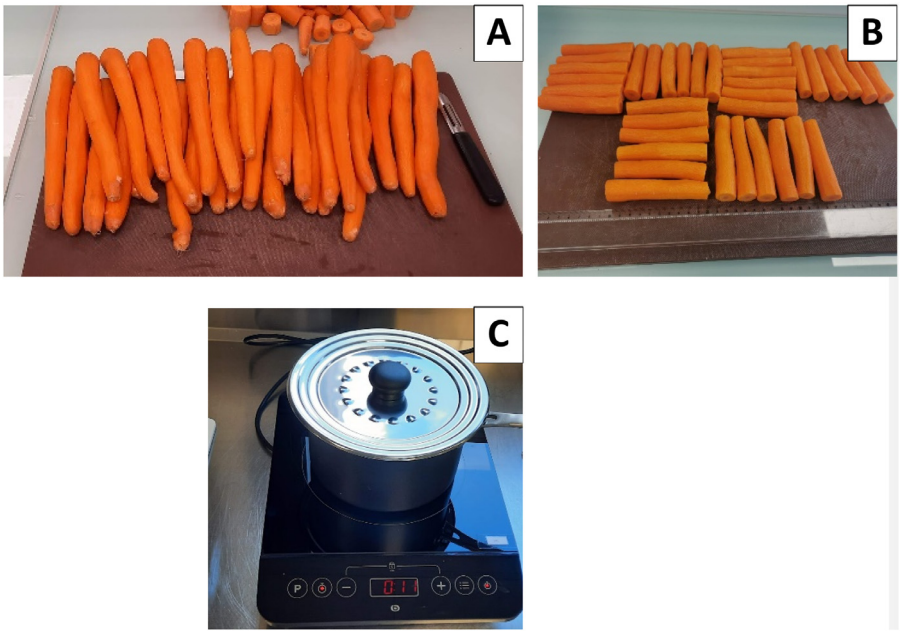

Fig. 1. Stages of carrot preparation—(A) Raw carrots after peeling, (B) Raw carrots after cutting and possible extra peeling, (C) Domestic cooking material.

diameter inferior to 1.6 cm were not used. Extra peeling was sometimes necessary to reach the size requirements. Extra peeling was done in such a way as to limit the waste of carrots of which a slight portion (1 to 2 cm in length) was above 2.2 cm in diameter after the first peeling process. A technical tip is to limit extra peeling as much as possible as this is not done in home settings and because the cells and tissues of the inner and the outer are different [4]. This selection of carrots allowed us to closely mimic domestic practices while ensuring uniformity in the carrots. A hand peeler was used to minimize the carrot modification and to mimic domestic practices. For the carrots for which extra peeling was necessary, the average weight was 42.28 g (SD = 4.4 g) before extra peeling and 38.18 g (SD = 2.5 g) after extra peeling. The weight loss was 4.11 g (SD = 2.9 g) (roughly 10% of the initial mass). In addition, only 1 to 2 cm of the 10 cm carrot was over peeled. Thus, the extra peeling was not considered critical for this methodology. The effect of extra peeling on the results was not analysed. The average carrots' weight (after peeling and extra peeling when necessary) was 33.4 g (SD = 4.7 g). The key point is that this selection and preparation procedure allowed to have carrots with similar length, weight, and diameter; they can thus be used to do repetitions (Fig. 1B). However, it is important to keep in mind that saccharides and amino acids composition can vary among the individual carrots of the same batch. This variability is important to the methodology presented here, as the consumer will face the same variability when cooking and eating carrots.

Cooking and salting process of carrots

Carrots were cooked in boiling mineral water (Evian, Danone, France). Mineral water was used to mimic the use of tap water, which usually contains minerals. Evian water was selected since it has a constant mineral composition over time, and Evian water especially has a medium mineralization level (total dissolved solids 300 mg/L), both of which contribute to the standardization of the methodology. Therefore, this methodology is closer to domestic practices compared to the use of ultrapure or distilled water. The heating process was ensured by a domestic induction hob (Essentielb EPI 1 reference #8009169, Boulanger®, France) (Fig. 1C). The type of pan used (Carrefour Home, France) had an internal diameter of 18 cm and a maximum volume of 2.5 L.

In our tests, we used varying vegetable-to-water ratios, depending on the specific experiment under consideration. In some cases, cooking a single carrot in 1 L of cooking water proved sufficient. For instance, physicochemical analyses like ionic chromatography (IC) or nuclear magnetic resonance (NMR) required no more than one carrot to be prepared. However, sensory experiments demanded a larger quantity of cooked carrots. In these experiments, 6 carrots had to be prepared simultaneously, per pot, in order to be able to serve samples to a large group of participants (n = 10).

French recipes of a traditional boiled carrot dish named "Carottes Vichy" suggest boiling times ranging from 20 min to 25 min [15–17]. Regarding the cooking temperature, vigourously boiling condition is not recommended, because maintaining the temperature at 100 °C for 25 min will result in a significant loss of water which could modify the cooking conditions by increasing the vegetable-to-water ratio. To limit water loss, the cooking temperature was maintained at 98 +/- 2 °C by setting the temperature target of the cooking hob at "100 °C" and a lid was used constantly during the cooking process. Using a lid also reduces the energy required to maintain the target temperature. A saucepan lid can make a sixfold reduction in energy consumption when simmering at 90 °C [18]. With this methodology, well-cooked carrots were achieved in 25 min. In these conditions (cooking for 25 min at 98 °C with a lid),

the water loss percentage was measured and was limited to 10% +/- 3%. At the end of the cooking process, the carrots were drained using a domestic colander.

During our tests, the carrots were cooked in two conditions: either with commercial iodized sea salt (La Baleine, France) added to water at the beginning of the heating process, or no salt added. According to the brand, the salt used is composed of 97.5% NaCl. Carrots cooked in unsalted water were either salted after the cooking process or left unsalted. For the samples cooked in salted water, 10 g of salt was added to the cooking water before adding the carrots. This level was chosen according to online recipes [19], discussions with chefs, and sensory internal tests. Carrots cooked at this level were considered as salty enough by an internal panel.

Examples of applications of the method

Three examples of scientific applications using this domestic-like cooking method are provided in this section, namely ionic chromatography measurements, sensory analysis, and NMR spectroscopy. Their objectives were respectively to assess sodium (Na^+) content in cooked carrots, to assess saltiness perception, and to assess interactions between Na^+ and the food matrix. The cooking methodology detailed in sections 1 and 2 has been tested in these three types of experiments. Therefore, variations of the method depending on the experiment at stake will be provided and discussed. Other applications can benefit from this methodology. They will be detailed in section 3. Ionic chromatography measurements were also performed to validate our methodology by giving insights on the cooking process repeatability regarding Na^+ diffusion in the food matrix.

Assessing sodium content using ionic chromatography (IC)

Na^+ content in cooked carrots was measured using IC. This analysis required liquid samples. Therefore, two carrots were prepared and cooked together in 1 kg of water according to the above-described methodology and were then blended and centrifuged. To do so, 0.5 cm carrot slices were made width wise after cooking. Then, all the pieces except the first ones at the two extremities, as these parts are more exposed to salt diffusion, were blended (Ultra-Turrax, Ika T25D, Germany) for 1 min at 15 000 rpm after the addition of 100 mL of MilliQ water (Millipore SAS, Molsheim, France) to facilitate the mixing. After 1 min at 15 000 rpm a puree without solid parts visible was obtained. The resulting carrot puree was centrifuged (Beckman Coulter, 20 °C, 30 min, acceleration max, deceleration min) for 30 min at 15 000 g. Finally, the supernatant was collected, filtered (pore size 0.45 µm, CIL, Sainte Foy la Grande, France) and diluted by a factor of 5 with MilliQ water for unsalted carrots and by 20 for salted carrots, before being poured into an HPLC vial.

An ion chromatograph ICS-3000 (Dionex, Sunnyvale, CA, USA) was used to determined Na^+ concentration in carrot samples. The ionic chromatograph was equipped with a conductivity detector, a guard column Dionex IonPac CG12A (5 µm particle size, 3 × 30 mm) and a separating column CS12A (5 µm particle size, 3 × 150 mm), a cation self-regenerating suppressor (CSRS ULTRA II 2 mm) with electrochemical methods. Eluent was 11 $mmol.L^{-1}$ of sulfuric acid (H_2SO_4), prepared from a 96% H_2SO_4 solution, at flow-rate 0.5 $mL.min^{-1}$. The pressure in the system was around 1500 psi (104 bars). The eluent was degassed with nitrogen gaz N_2 with a pressure of 2.5 bars in bottle. The filtered sample was put in a vial (batch #420761 PN 50026635 V2-2 USA), thermo-controlled at 10 °C by autosampler (AS) and injected into a 10 µL sample loop of the Dionex ICS-3000 system. The Na^+ standard solution was prepared by dissolving 125.3 mg of NaCl (CAS 7647-14-5 Sigma Aldrich S9625-1 kg #SLBW8510) into 200 ml MilliQ water (18.2 MW.cm) to yield the assay concentration of 10.7 mM (= 626.5 mg/L). Dilution of the stock solution was made from 0.06 to 2.1 mM (3–125 mg/L) in this same MilliQ water. Data were acquired by using Chromeleon chromatographic data station software (version 7.2).

Na^+ measurements were made on carrots cooked in water salted at 0, 86 and 171 mmol of Na^+/L of cooking water (equivalent to 0, 5 and 10 g of salt/L), in triplicates (for each repetition the whole preparation and cooking process was repeated, 2 carrots were cooked per repetition). The same measurements have been performed in triplicates on carrots cooked in water salted at 342 mmol of Na^+/L (equivalent to water salted at 20 g of salt/L, 1 carrot cooked per repetition). Carrots were prepared and cooked in 1 kg of water following the methodology described above.

Na^+ concentration was found to be 10.57 mmol/L (SD = 2.0 mmol/L) of supernatant collected after centrifugation for unsalted carrots. It was 45.45 mmol/L (SD = 2.2 mmol/L), 75.14 mmol/L (SD = 8.6 mmol/L), 105.89 mmol/L (SD = 5.8 mmol/L), of supernatant collected after centrifugation for carrots salted with 86, 171, and 342 mmol of Na^+/L of cooking water respectively (Fig. 2). The coefficients of variation were 18.7%, 4.9%, 11.5% and 5.5% for carrots salted at 0, 86, 171, and 342 mmol of Na^+/L of cooking water respectively. These results confirmed the repeatability of the cooking process when considering Na^+ measurements.

To investigate whether the number of carrots cooked in the water influenced the Na^+ transfer inside the carrot, we conducted experiments using $n = 6$ carrots at Na^+ molar concentrations of 86 and 171 mmol/L. Each salting modality was repeated three times. The results showed no significant differences in Na^+ concentration compared to cooking with 2 carrots at the same salt concentration levels (at 86 mmol/L: $t(2.3) = 1.9$, $p = 0.173$, at 171 mmol/L: $t(3.5) = 1.3$, $p = 0.270$). Thus, the diffusion of Na^+ inside the carrots remained unaffected, regardless of whether 2 or 6 carrots were cooked. This suggests that the methodology can be utilized for applications that involve cooking a limited number of carrots, while ensuring a similarity to domestic practices in which the ratio of vegetable-to-water ratio is often higher than 2 carrots per liter of cooking water.

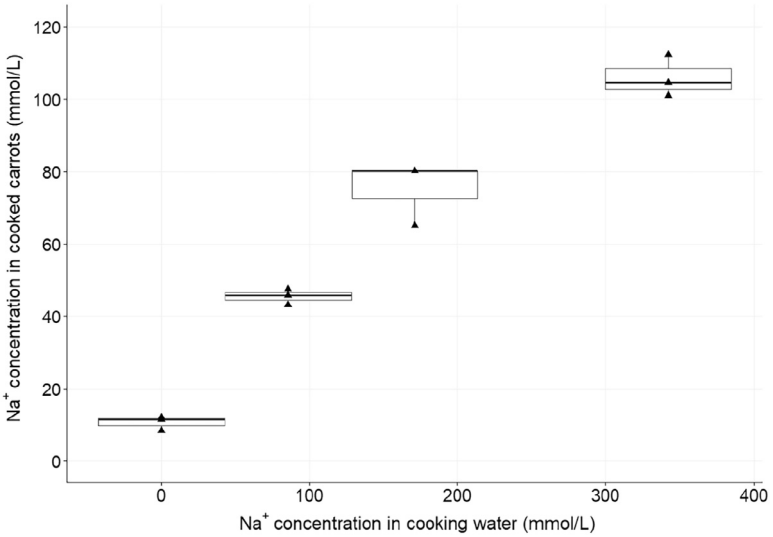

Fig. 2. Na^+ concentration in cooked carrots as a function of the salt level used in the cooking water. Each triangle represents a repetition. The bold bar represents the median of three repetitions.

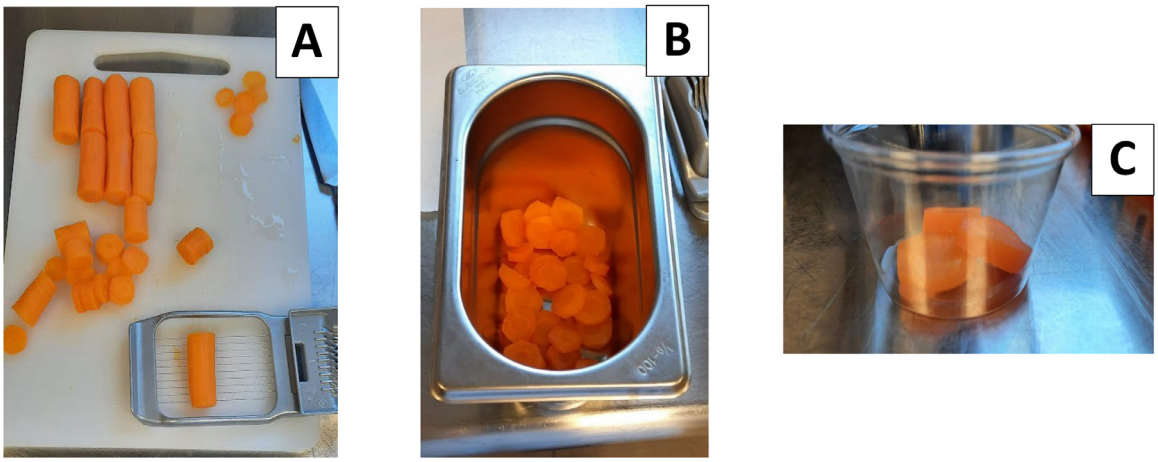

Fig. 3. Carrot samples for sensory evaluation experiment- (A) Cooked carrots cut into uniform pieces using an egg slicer (B) Carrot slices stored in 1/9 Gastro-Norm tray. (C) A sample prepared for sensory evaluation comprising 3 carrot pieces with a width of 0.5 cm each.

Assessing saltiness perception through sensory evaluation

Saltiness perception was assessed by a sensory panel (data not shown). To conduct this analysis, a larger number of homogeneous carrot samples needed to be prepared and served to the participants. Accordingly, 6 carrots (m = 200 +/- 10 g) were prepared and cooked in 1 kg of water following the methodology described above. Although it is not a usual domestic practice, the 0.5 cm extremities of the carrots were removed after the cooking process, as these parts are likely more exposed to salt diffusion. This step was necessary to mitigate potential biases due to these potentially saltier parts, irrespective of our target factors. However, since it is not a practice in home settings, it is recommended to minimize the thickness of the removed cooked parts. Removing 0.5 cm carrot extremities constituted only 10% of the cooked carrot, a percentage we considered acceptable.

The carrots were sliced into 0.5 cm lengths using a stainless-steel wire egg slicer (Westmark, Germany) (Fig. 3A). The carrot pieces were placed into closed stainless steel 1/9 Gastro-Norm trays and kept in a 60 °C bain-marie (Fig. 3. B). Each sample for the participants consisted of three pieces of carrots (m = 4.3 g (SD = 0.3 g)) (Fig. 3C). The serving temperature was 39.5 °C (SD = 2.7 °C).

Assessing interactions between Na^+ and the food matrix using NMR spectroscopy

NMR was used to investigate the interactions between the carrot matrix and the Na^+ that enters the carrot during the cooking and salting process (data not shown). This approach required a limited amount of carrots (from 0.40 g to 0.64 g; on average 0.51 g);

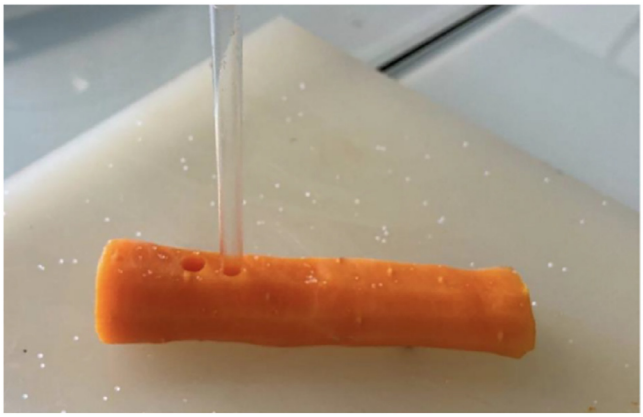

Fig. 4. Sample preparation for NMR spectroscopy analysis of Na^+ binding in the carrot food matrix salted after cooking (samples were taken along the whole width of the carrot).

hence, only one carrot was prepared and cooked in 1 kg of water following the methodology described above. After cooking, a sample was taken width wise from the middle of the cooked carrot, inserted into a 5-mm NMR tube (Fig. 4). Then, the interactions between Na^+ and the food matrix were investigated, providing valuable information on Na^+ binding in the food matrix when carrots are prepared according to usual consumer practices in their kitchens. For this experiment, the salt level in the water was fixed at 20 g/L to ensure accurate results with ^{23}Na NMR.

Other applications

It is important to explore the broader scope of potential applications for this laboratory-standard cooking method, which mimics domestic practices. One notable area where this method can be applied is in agronomy, where it can be employed to effectively monitor contaminants and assess pesticide persistence following cooking. In this context, studies would involve replicating common household cooking procedures to precisely determine the levels of chemical residues that consumers may be exposed to when consuming vegetables like carrots. Additionally, this method can be used to evaluate the loss or retention of vitamins and minerals in vegetables, such as carrots, after boiling. Furthermore, it's important to highlight that the core principles underpinning this methodology can be adapted to prepare samples from a diverse array of vegetables and cereals. This versatility makes the method a valuable and versatile tool with extensive applications in the field of food research.

Advantages and limitations of the method

This methodology aims at mimicking domestic practices, utilizing common kitchen materials, employing the same cooking methods as those used at home, selecting cooking time based on common recommendations in recipes, and purchasing carrots from a local supermarket.

However, a limited number of steps had to be standardized to ensure a scientific approach, including maintaining a consistent carrot size, using Evian water with a constant mineral content for cooking, ensuring uniform slices, and removing carrot extremities to mitigate biases related to salt content heterogeneity. It is essential to acknowledge these differences when applying this methodology. Nonetheless, in our view, these adjustments are necessary to yield robust data that can be replicated by other researchers.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Raphaël Monod: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft. **Sylvie Clerjon:** Conceptualization, Methodology, Writing – review & editing, Project administration. **Cécile Leroy:** Conceptualization, Methodology. **Chantal Septier:** Methodology, Investigation, Writing – review & editing. **Bérénice Houinsou-Houssou:** Methodology, Investigation, Writing – review & editing. **Hervé This:** Methodology, Writing – review & editing. **Christian Salles:** Conceptualization, Methodology, Writing – review & editing. **Thierry Thomas-Danguin:** Conceptualization, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Data availability

Data will be made available on request.

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