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(Research Article)

Study of the stability of iodine during cooking and storage of salts produced from Palmaceae branches

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Abstract

Palmaceae salts, from a previous study, do not contain iodine. The addition of iodine having to respect very precise rules, a study of their iodization as well as the behaviour of the iodine within them was essential. Thus, palm and coconut branches salts were iodized using two types of dietary iodine: potassium iodate and potassium iodide. Subsequently, their abilities to maintain high iodine levels during storage, package in glass jars and in plastic bags, has been tested in market and laboratory conditions. The stability of iodine during cooking was also studied. The study shows that the biggest losses were recorded for salts bagged and kept at the market. These losses go up to 3% after 3 months of storage. However, regarding glass jars, the loss rates do not exceed 1%, whatever the conservation conditions. Furthermore, cooking does not constitute a factor in the loss of iodine in plant salts. Indeed, at maximum cooking times and temperatures, the loss rates observed were not the highest. Fluctuations in this case could be related to sampling and assay techniques. Ultimately, plant salts proposed for the diet of people following low-salt diets can also serve as a means of supplementing iodine.

Keywords: Metabolic diseases; Sodium/potassium ratio; Salt-free diet; Indigenous salts; Potash

1. Introduction

The very high prevalence of diseases linked to excessive sodium consumption means that the search for salty products, low in this mineral, is very encouraged. This sparks interest in any alternative salt that contains less sodium. Palmaceae salts have sodium/potassium ratios much lower than the standard for products reserved for low-sodium diets (< 1) [1,2]. They contain many other minerals such as calcium, zinc and magnesium. However, they contain almost no iodine [3]. People following low-sodium diets are deprived of iodized salt and often other iodized products such as oil and various seasonings [4,5].

Iodine is an essential element for the proper functioning of the body. Iodine deficiency can be the cause of many diseases such as cretinism and goitre [6]. It is therefore imperative that any table salt replacement product, intended for these people, be previously iodized according to international standards [7].

The objective of this work is to offer salty products low in sodium and capable of maintaining high iodine levels after storage or cooking. He would also like to give an alternative to severe low-salt diets, which are unbearable and often imposed in cases of pathologies such as high blood pressure.

The scientific approach initially consisted of proposing a method for iodizing plant salts. Secondly, it was a question of studying the variations in iodine levels in plant salts during storage and during water-cooking.

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2. Material and methods

2.1. Material

Salts from palm (Figures 1) and coconut (Figures 2) branches were the subject of this study. These plant salts were produced under the same conditions, according to the diagrams describe by [2] (Figure 3). For the storage of iodized plant salts, high density polyethylene (HDPE) bags (OK PLAST brand, Ivory Coast) and glass jars, found commercially, were used. Furthermore, potassium iodate (KIO_3) was the form of iodine used. Fine iodized sodium chloride (Saline F brand) served as a control.

Figure 1 Plant salt extracted from palm branches (*Elaeis guineensis*)

Figure 2 Plant salt extracted from coconut branches (*Cocos nucifera*)

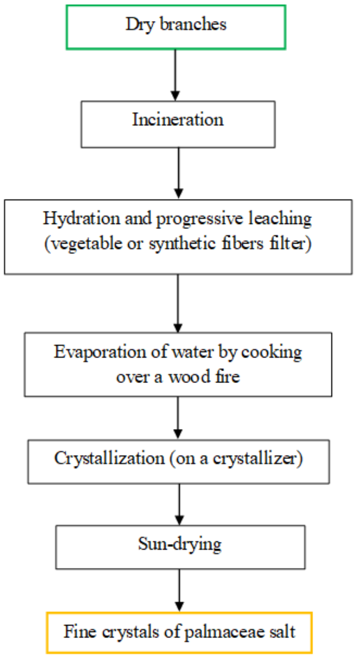

Figure 3 Artisanal manufacturing process for plant salts [2]

2.2. Methods

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2.2.1. Plant salts iodizing method

The recommended iodization rate for a food additive such as table salt is between 30 and 170 mg of iodine/kg [8]. As part of this study, the objective was to ultimately obtain 100 mg of iodine per kg of salt. Therefore, it was added to the salts, 168.5 mg of potassium iodate, taking into account the molar mass of the compound. Iodate compound (KIO_3) was powdered and mixed manually with a load (small quantity of salt to iodize). The fine mixture obtained was added to the rest of the salt and mixed.

2.2.2. Plant salts iodine level measuring method

The determination of iodine rate was carried out by the iodometric titration described by [7]. Given the alkalinity of plant salts and that the reaction takes place in an acidic environment, the test portions were all limited to 1 g to avoid violent reactions. To fix the iodine in plant salts containing KIO_3, potassium iodide (KI) - 10% was used as redox couple.

Distilled water (100 ml) and 1 g of iodized salt were introduced into an Erlenmeyer flask. After complete dissolution by stirring, 5 mL of KI - 10% and 3 mL of sulphuric acid (H_2SO_4, 2N) have been added. The solution turned light yellow. The Erlenmeyer flask was capped and placed in the dark in a closet for 10 min. After 10 min of incubation, the yellow shade was darker, and 3 mL of a starch solution was added to the mixture. The solution turned dark blue (or dark purple). The contents of the Erlenmeyer flask were titrated with sodium thiosulfate 0.01N. The titration continued until the blue colour disappeared and the solution returned to its initial colour.

2.2.3. Plant salts iodine level calculation

Whatever the form of the added iodine, the titration in its I_2 form by the sodium thiosulfate is made following the reaction:

$$I_2 + 2\,S_2O_3^{2-} \rightarrow 2\,I^- + S_4O_6^{2-}$$

$$n_{Thio} = 2n_{I_2}$$

So

$$C_{Thio} \times V_{Thio} = 2 \times C_{I_2} \times V_{I_2}$$

Now

$$m_{I_2} = M_{I_2} \times C_{I_2} \times V_{I_2}$$

The calculation of the iodine content (mg/kg of salt) of the iodized plant salts was therefore done using the formula:

$$T = \frac{C_{Thio} \times V_{Thio} \times M_I}{P_e} \times 1000$$

With:

T: iodine content (mg/kg or ppm); $\boldsymbol{m_{I_2}}$: mass of I_2 (mg); **M_I:** molar mass of iodine (127 g.mol-1); **V_{Thio}:** volume of sodium thiosulfate read on the burette (mL); **C_{Thio}:** practical molar concentration of sodium thiosulfate (mol/L); **Pe:** salt test intake (mg).

2.2.4. Iodine behaviour in plant salts

Iodine level monitoring during water-cooking

The temperature was varied from 70 to 100 °C by 10 °C intervals. The cooking was carried out at 30 min, 1 hour, 1 hour 30 min and 2 hours [9]. The iodized plant salt (1 g) was dissolved in 100 mL of distilled water. The quantity of iodine was measured by iodometric titration and the calculation of the iodine content was done according to the methods mentioned above [7].

For each iodized salt, the studied parameters were annotated as follows: $Salt_{\text{type of iodine}}$ (Temperature; time). For example, SBP_{iodate} (70 °C; 10) for palm salt iodized with potassium iodate, heated to 70 °C for 10 min

Iodine level monitoring during storage

The plant salts were packaged in high density polyethylene (HDPE) bags and in glass jars. (Figure 4). Two storage locations were targeted for this study: a laboratory closet (T° = 17-25°C) and a stall at the Odienne market. Iodine level measurements were carried out every week for 3 months, by iodometric titration. The calculation of the iodine content was done according to the methods mentioned above [7].

Figure 4 Plant salts packaged in: A- high density polyethylene (HDPE) bags; B- glass jars

2.2.5. Iodized plant salts humidity level measurement after storage

After 3 months of storage, the humidity rate of the packaged salts was measured according to [10]. The measurements were carried out by differential weighing between the test portion (Pt) and the mass after drying in a crucible. The humidity rate was calculated as follows:

$$H\ (\%) = \frac{M1 - \mathrm{M2}}{Pt} \times 100$$

With:

***H**: Humidity rate (%)*; ***Pt**: Test portion (g)*; ***M1**: mass (g) of the whole (capsule + salt) before steaming*; ***M2**: mass (g) of the whole (capsule + salt) after steaming.*

2.3. Statistical analysis

The one-way analysis of variance (ANOVA 1) using the type of salt and the region as explanatory variables was carried out using the JMP® Version 18.0.1, 2024 software. The Tukey test allowed the comparison of averages at the 5% threshold. The explanatory variables were the type of plant salt, the packaging, cooking and storage temperatures and times. Variables explained were the quantities of iodine measured and the loss rates.

3. Results and discussion

3.1. Iodization and behaviour of iodine in plant salts

The use of salt is an effective means of supplementing populations with iodine due to its non-expiration and the possibility of quantifying its consumption [11]. However, the addition of iodine to a food depends above all on its ability to maintain a significant concentration over time, depending on the constraints linked to its conservation and use [12]. In this study, a method for measuring iodine within plant salts was proposed. The effective amounts of iodine in plant salts after iodization are presented in Table 1.

Table 1 Iodine level after plant salts iodization

	SBP_{iodate}	**SBC_{iodate}**	**$NaCl_{iodate}$**
Iodine (mg/kg)	97.57 ± 2.12	108.63 ± 0.25	130.1 ± 1.81

SBP_{iodate} and **SBC_{iodate}** for plant salts iodized with potassium iodate (KIO_3); **$NaCl_{iodate}$** for the fine sodium chloride (control) iodized with potassium iodate

3.1.1. Plant salts iodine behaviour after cooking

Cooking did not influence the iodine in plant salts. Indeed, if cooking were a factor in iodine loss, the rate of reduction, for a given temperature would increase over time. Also, this rate of reduction would reach its maximum for the longest cooking time at the highest temperature. However, this is not the case. Furthermore, when the iodine level fell, this reduction was not significant. Indeed, the highest loss rates of iodine, for each of the salts previously mentioned, were reached at the level of SBP_{iodate} (90 °C; 1h) = 94.32 ppm and SBC_{iodate} (70 °C; 1h30) = 107.33 ppm (Table 2). These results clearly indicate that the lowest iodine levels do not necessarily correspond to the highest temperatures and cooking times. The distribution of the values obtained also does not correspond to a gradual decrease in iodine over time and with increasing temperature. The reductions in iodine recorded could, in this case, be linked to the vagaries of micrometre-accurate measurements, which are difficult to achieve. Thus, for domestic cooking temperatures, iodine remains stable in plant salts. Seid Ali *et al.* [9] obtained, under the same experimental conditions, that cooking was not a factor in iodine loss during work carried out on several table salts in Senegal.

Table 2 Iodine level evolution according to the temperature and the cooking time

Iodized salt / Temperature	**Cooking time / Iodine level (ppm)**			
SBP_{iodate}	30 min	1h	1h30	2h
70 °C	97.57 ± 0.32^{Aa}	97.57 ± 0.58^{Aa}	95.62 ± 0.23^{Aa}	97.57 ± 2.25^{Aa}
80 °C	97.57 ± 0.11^{Aa}	9.57 ± 1.9^{Aa}	96.92 ± 0.14^{Aa}	96.27 ± 0.27^{Aa}
90 °C	97.57 ± 0.05^{Aa}	94.32 ± 0.71^{Aa}	97.57 ± 1.03^{Aa}	95.43 ± 1.01^{Aa}
100 °C	97.57 ± 0.87^{Aa}	97.57 ± 1.25^{Aa}	95.62 ± 0.07^{Aa}	96.92 ± 0.52^{Aa}
SBC_{iodate}	30 min	1h	1h30	2h
70 °C	107.98 ± 0.41^{Aa}	107.98 ± 1.10^{Aa}	107.33 ± 0.02^{Aa}	107.98 ± 0.18^{Aa}
80 °C	108.63 ± 0.07^{Aa}	107.53 ± 0.76^{Aa}	108.63 ± 1.02^{Aa}	108.63 ± 0.09^{Aa}
90 °C	107.98 ± 1.01^{Aa}	108.11 ± 0.19^{Aa}	107.98 ± 0.50^{Aa}	107.98 ± 0.67^{Aa}
100 °C	108.63 ± 0.16^{Aa}	107.98 ± 0.24^{Aa}	108.63 ± 0.75^{Aa}	107.33 ± 0.35^{Aa}
$NaCl_{iodate}$	30 min	1h	1h30	2h
70 °C	130.10 ± 0.37^{Aa}	130.10 ± 0.08^{Aa}	129.45 ± 1.07^{Aa}	130.10 ± 0.21^{Aa}
80 °C	130.10 ± 2.34^{Aa}	128.80 ± 1.07^{Aa}	130.10 ± 0.11^{Aa}	130.10 ± 0.01^{Aa}
90 °C	128.47 ± 0.75^{Aa}	128.15 ± 0.33^{Aa}	127.50 ± 2.93^{Aa}	129.45 ± 0.33^{Aa}
100 °C	130.10 ± 0.35^{Aa}	128.67 ± 0.06^{Aa}	128.80 ± 0.37^{Aa}	127.50 ± 2.05^{Aa}

For each salt, the values assigned to the same lowercase letter on the same row and the values assigned to the same uppercase letter in the same column are not significantly different at the 5% threshold (Tukey test).; **SBP_{iodate}**: palm branches salts iodized with potassium iodate; **SBC_{iodate}**: coconut branches salts iodized with potassium iodate; **$NaCl_{iodate}$**: sodium chloride iodized with potassium iodate.

3.1.2. Plant salts iodine behaviour during storage

The reduction in iodine during storage was more significant with HDPE than with glass (Table 3 and 4). This difference is necessarily linked to the intrinsic properties of the packaging. Indeed, the plant salts in the plastic bags gained moisture after three months of storage in the laboratory (nearly 0.5%) and especially at the market (nearly 2%) (Table 5). The salts in the glass jars recorded less than 0.3% increase in humidity at the market compared to 0% in the laboratory. The diffusion of water vapour inside the packaging can cause the migration of iodine to the bottom or to the outside [8]. Perhaps a faulty crimping would have amplified this water intake. Nevertheless, HDPE remains a good packaging for iodized plant salts. Indeed, according to Seid Ali et al. [9], this loss of iodine is not significant. However, glass remains safer as noted by Assoumanou et al. [13] as well as Djonga et al. [14] during their studies on iodine deficiency in Benin and Mali respectively.

Table 3 Iodine losses in iodized salts packaged in plastic bags

	Loss level (%)	
Type of salt	**Market conditions**	**Laboratory conditions**
$NaCl_{iodate}$ (control)	3.46	2.31
SBP_{iodate}	3.33	1.20
SBC_{iodate}	4.01	1.25

SBP_{iodate}: palm branches salts iodized with potassium iodate; **SBC_{iodate}**: coconut branches salts iodized with potassium iodate; **$NaCl_{iodate}$**: sodium chloride iodized with potassium iodate

Table 4 Iodine losses in iodized salts packaged in glass jars

	Loss level (%)	
Type of salt	**Market conditions**	**Laboratory conditions**
$NaCl_{iodate}$ (control)	0.00	0.00
SBP_{iodate}	0.00	0.00
SBC_{iodate}	0.61	0.00

SBP_{iodate}: palm branches salts iodized with potassium iodate; **SBC_{iodate}**: coconut branches salts iodized with potassium iodate; **$NaCl_{iodate}$**: sodium chloride iodized with potassium iodate.

Table 5 Iodized salts humidity after three months of storage

	Market conditions		**Laboratory conditions**	
	Plastic bag	**Glass jar**	**Plastic bag**	**Glass jar**
SBP_{iodate}	1.96 ± 0.02^a	0.28 ± 0.00^c	0.51 ± 0.00^b	0.00^d
SBC_{iodate}	1.95 ± 0.06^a	0.27 ± 0.00^c	0.49 ± 0.00^b	0.00^d
$NaCl_{iodate}$	1.35 ± 0.11^a	0.27 ± 0.00^c	0.50 ± 0.00^b	0.00^d

For each salt (packaged at the market or at the laboratory), the values assigned to the same lowercase letter on the same row are not significantly different at the 5% threshold (Tukey test).; **SBP_{iodate}**: palm branches salts iodized with potassium iodate; **SBC_{iodate}**: coconut branches salts iodized with potassium iodate; **$NaCl_{iodate}$**: sodium chloride iodized with potassium iodate.

4. Conclusion

The objective was initially to iodize plant salts and to verify the stability of the iodine in these products. Iodized plant salts, if well packaged, can preserve iodine for more than three months. For this purpose, high density polyethylene (HDPE) plastic bags are good packaging for these products. However, glass remains the safest means of preservation in conditions of high humidity.

Compliance with ethical standards

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Disclosure of Conflict of interest

All authors declare that they have no competing financial interests, no known conflicts of interest associated with the publication of this manuscript. The authors also disclose conflict of interest with products that compete with the one mentioned in this manuscript

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