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Household Knowledge of Iodized Salt and Iodine Content of Dietary Salt in Morocco Further 25 Years of Universal Salt Iodization: A National Cross-Sectional Study

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ABSTRACT

Background: At the global level, iodine deficiency (ID) has been significantly reduced since the widespread implementation of salt iodization programs; nevertheless, numerous populations worldwide remain at risk of insufficient iodine intake. In Morocco, the Universal Salt Iodization (USI) strategy was formally adopted in 1995 as a national public health measure to address this nutritional challenge. However, to date, no comprehensive national study has been conducted to evaluate the impact of this strategy on iodine adequacy at the household level.

Aims: This cross-sectional study aims to assess the iodine content of dietary salts at the household level in Morocco on a national scale.

Methods: A national cross-sectional study was conducted in 2019 among Moroccan households (n = 1963). Dietary salt samples were systematically collected from surveyed households to estimate household coverage of adequately iodized salt and to evaluate consumer awareness of iodization labelling. Iodine content analysis was performed employing the standardized iodometric titration method.

Results: At the national level, the majority of households predominantly consumed packaged salt (89%), whilst bulk salt accounted for only 8.1% of total consumption. Packaged salt was significantly more prevalent in urban areas (93.3%), whereas bulk salt was more frequently consumed in rural areas (14%) ($p < 0.05$). Consistently, the majority of surveyed households (71%) were unaware of the "*iodized salt*" designation on product labelling. The median iodine content of salt samples collected from the 1,963 households was 7.40 ppm (CI: 7.4–8.0), indicating that only 7.5% (95% CI: 6.4–8.7) of the surveyed population consumed adequately iodized salt (15 – 40 ppm). Furthermore, 65.6% (95% CI: 63.5–67.7) consumed inadequately iodized salt (5–14.9 ppm); 25.7% (95% CI: 23.8–27.6) consumed non-iodized salt (< 5 ppm); and 1.2% (95% CI: 0.8–1.8) consumed over-iodized salt (> 40 ppm).

Conclusion: Household coverage of adequately iodized salt remains critically low in Morocco, 25 years following the adoption of the USI strategy, underscoring the limited effectiveness of current program implementation. These findings highlight the urgent to reinforce and comprehensively revise the national salt iodization strategy through enhanced regulatory oversight, strengthened supply chain monitoring, improved consumer awareness campaigns, and targeted interventions in rural and nutritionally vulnerable populations, in order to fulfil the public health objectives of sustainable iodine deficiency elimination.

Keywords: Iodine Deficiency; Salt Iodization; Morocco; Iodometric Titration; Public Health Nutrition.

Article Information

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1 INTRODUCTION

Iodine is a trace element present in the human body in extremely low quantities (10-15 mg). The essential role of iodine in human metabolism is to provide the building blocks for the synthesis of thyroid hormones: thyroxine and triiodothyronine (T3) (Zimmermann, 2009).

Iodine deficiency disorders (IDD) constitute a major obstacle to economic development, causing irreversible neurological damage and social and economic exclusion (De Benoist *et al.*, 2002). It is estimated that two billion individuals in the general population exhibit an inadequate iodine intake (De Benoist *et al.*, 2008). Every year, 38 million children are born at risk of brain damage due to iodine deficiency (UNICEF, 2008). To eliminate IDD, the World Health Organization (WHO) recommends universal salt iodization (USI) (WHO, 2007) and has limited daily salt consumption to 5 g per day (WHO, 2007).

To reduce the incidence of IDD, the WHO and the United Nations Children's Fund (UNICEF) have jointly recommended USI as the primary public health strategy for the elimination of iodine deficiency. Optimal iodine preservation under this strategy is ensured through the storage of iodized salt away from direct light and in hermetically sealed containers, as well as by employing fine granulation to maximize iodine retention. USI is recognized as a safe, cost-effective, and sustainable intervention, guaranteeing a sufficient and reliable supply of iodine to the entire population when implemented with fidelity (Iodine Global Network [IGN], 2015).

The global strategy to address ID through the large-scale fortification of food-grade salt with iodine has yielded remarkable and well-documented progress. Iodized salt is actually available in approximately 87% of households worldwide (UNICEF, 2017), and the number of countries classified as iodine-deficient has declined from 54 to 20 over the past 15 years (Andersson *et al.*, 2005; IGN, 2017). The WHO recommends that salt iodization be implemented on a universal basis, defining USI as: (1) the iodization at 20-40 mg/kg of all food-grade and reserve salt, including salt utilized in food manufacturing and processing; and (2) the consumption of adequately iodized salt (≥ 15 mg/kg) by more than 90% of households (WHO, 2007). This target is predicated on the assumption that a mean daily salt intake of 5 g/d at an iodine concentration of 15 mg/kg will provide an estimated 100 – 150 μg of iodine per day for adult consumers (WHO, 2007).

Historically, iodine deficiency constituted a severe public health concern in Morocco. A seminal epidemiological investigation by Zimmermann *et al.* (2004) revealed a median urinary iodine concentration (UIC) of 17 μg/L among school-aged children in northern Morocco, accompanied by a goiter prevalence of 72%, confirming the presence of severe iodine deficiency in this population. In response to this documented public health emergency, Morocco formally adopted the USI strategy in 1995, mandating the iodization of all table salt intended for human consumption and introducing a consumer-facing logo to facilitate the identification of iodized salt products at the point of purchase.

Notwithstanding these public health measures, recent epidemiological evidence indicates that iodine deficiency persists among specific and vulnerable population subgroups in Morocco. Saeid *et al.* (2018) assessed the iodine status of 131 Moroccan children and adolescents, reporting that 72.5% were classified as iodine-deficient, with a median UIC of 96 μg/L. Rami *et al.* (2022) conducted a national survey among 1,652 women of reproductive age, reporting a median UIC of 71.3 μg/L and finding that 71% of women exhibited a UIC below 100 μg/L, indicative of mild iodine deficiency within this vulnerable group. Furthermore, El Ammari *et al.* (2021) evaluated iodine nutrition in 1,043 Moroccan children aged 6–12 years, reporting a national median UIC of 117.4 μg/L, which satisfies the WHO threshold for iodine sufficiency at the aggregate national level. However, this national average conceals significant and clinically important subnational disparities: 21.6% of children exhibited a UIC below 50 μg/L — a proportion exceeding the WHO threshold of 20% — and Zone 3, comprising the central, high-altitude, and non-coastal regions of the country, remained iodine-deficient with a median UIC of 89.2 μg/L ($p < 0.004$).

Despite a marginal improvement in aggregate iodine status at the national level since the implementation of the USI strategy, iodine deficiency persists among specific vulnerable population subgroups in Morocco. A critical and prior unaddressed gap in the existing evidence base is the absence of any national-level study systematically evaluating whether the salt actually consumed by Moroccan households meets the established iodization standards mandated under the USI program. The present study was therefore designed to address this evidence gap directly.

The primary objective of this study was to evaluate the effectiveness of Morocco's national USI strategy 25 years following its formal adoption. More specifically, the study aimed to: (1) quantify the iodine content of salt consumed at the household level across Morocco; (2) assess the reliability of the "*iodized salt"* logo as a practical and trustworthy indicator of actual iodine content; (3) estimate the proportion of Moroccan households consuming adequately iodized salt in accordance with international standards; and (4) evaluate the level of household awareness and knowledge towards the "*iodized salt"* designation and its public health significance.

2 Material & Methods

The present study was conducted as an integral component of the National Nutrition Survey 2019, carried out by the Moroccan Ministry of Health between 2019 and 2020, with the primary aim of determining whether the national USI strategy had produced a measurable and meaningful impact on the iodine nutritional status of the most vulnerable population groups at the national level. The survey was designed and implemented in accordance with UNICEF guidelines for the collection of nationally representative data from Moroccan households across all 12 administrative regions of the country, covering four geographically defined zones: (1) a coastal and mountainous zone comprising the northern and eastern regions; (2) a coastal and non-mountainous zone limited to the western regions; (3) a non-coastal, high altitude zone characterizing the central regions of the country; and (4) a coastal, mountainous, and desert zone comprising all southern regions. Field data collection was conducted between June and December 2019.

The study population included all Moroccan households surveyed as part of the National Nutrition Survey 2019. Heads of Household who had resided in the survey area for a minimum of six months prior to the date of data collection were considered eligible for inclusion. The six-month residency criterion was applied to ensure that participants had been sufficiently exposed to local dietary practices prevailing in the survey area — including the types of salt typically purchased and consumed — thereby minimizing the risk of misclassifying dietary habits attributable to prior residence in other geographical regions. Given that the study focused on salt use practices and consumer knowledge rather than biological measurements, this criterion was considered appropriate and sufficient for defining the eligible study population. Participation was entirely voluntary, and written informed consent was obtained from all participating household heads prior to enrolment.

2.1 Study Design

This study employed a cross-sectional descriptive design, utilizing both qualitative and quantitative data collection methodologies to assess the iodine content of salt used at the household level and to systematically collect information on household knowledge of the factors influencing iodized salt consumption and purchasing behavior.

2.2 Socioeconomic Status Assessment

Data on socioeconomic status were collected through structured face-to-face interviews with household heads, using a standardized questionnaire developed as part of the study protocol. Variables collected encompassed the educational attainment of the head of household, household size, housing occupancy status, and overall and food-specific household expenditures.

For the purposes of data analyses, a composite well-being index was constructed, assigning scores to households on the basis of the number and type of durable goods owned and the physical characteristics of the dwelling, including access to a safe water supply, sanitary facilities, and flooring materials. These composite scores were generated through principal component analysis (PCA). The inclusion of the well-being index in the analytical framework was justified by the recognized influence of socioeconomic factors on household access to adequately iodized salt; in Morocco, properly packaged, iodized salt may retail at up to five times the price of non-iodized or under-iodized alternatives, a price differential that is likely to exert a significant influence on consumer purchasing decisions — particularly in contexts where awareness of the public health benefits of iodized salt consumption remains limited.

2.3 Recruitment and Sampling Strategy

The required minimum sample size was calculated through the standard formula for multi-stage cluster sampling:

$$n = \frac{\mathrm{d_{eft}}[\mathrm{z}^2 \times \mathrm{p} \times (1-\mathrm{p}) \times \mathrm{D} \times 1.10]}{\mathrm{er}^2 \times \mathrm{p}}$$

Where: deft = 1.5, z = 1.96, p = 0.30, D = 6 domains, er = 0.15–0.16, and a non-response correction of 10%. The required sample size was 3600 households, sufficient to estimate proportions ≥ 30% with a relative margin of error of 15–16% at the national level, stratified by urban and rural area of residence.

A complex, three-stage, stratified probability sampling design was employed to recruit 3,600 households, comprising 2,400 urban and 1,200 rural households. In the first stage, 180 primary units — 120 urban and 60 rural — were selected through probability proportional to size (PPS) sampling, based on data derived from the 2014 Population and Housing Census (RGPH) and the STEPS-2018 survey sampling framework. In the second stage, a secondary sampling unit comprising 50 households was drawn from within each selected primary sampling unit. In the third and final stage, 20 households per cluster were selected via single-point systematic sampling with equal probability, based on household enumeration forms completed on the day immediately preceding the survey visit. All analyses reported in the present study are based on appropriately weighted data, with weighting procedures applied to ensure full national representativeness by area of residence.

2.4 Analysis of Iodine Concentration in Collected Salt Samples

Salt samples, of 30–50 g, were collected from the salt in active use for meal preparation in each surveyed household. All samples were stored individually in zip-lock polyethylene bags to prevent moisture absorption and associated iodine degradation during transport and storage. Where a household was found to utilize more than one type of salt simultaneously — such as fine and coarse salt — each type was collected and stored separately in individually labelled bags to allow independent analysis.

The iodine concentration of all salt samples was determined employing the iodometric titration reference method, in strict accordance with the standardized procedure described by Dearth-Wesley *et al.* (2004). Each sample analysis was performed in triplicate to ensure analytical reproducibility. The iodine content was expressed in parts per million (ppm) and calculated using the following formula:

$$\mathrm{IC} = \frac{[(\text{Volume } Na_2S_2O_3) \times 21.15 \times \text{Normality } Na_2S_2O_3 \times 1000]}{\text{Mass of titrated salt sample (g)}}$$

The reference standard applied for the evaluation of salt iodine adequacy was that jointly established by the WHO and UNICEF (2015), whereby a minimum of 90% of surveyed households must have access to salt with an iodine content of ≥ 15 ppm (WHO, 2007). All iodine content analyses were conducted at the Joint Research Unit in Nutrition and Food, RDC-Nutrition AFRA/IAEA, CNESTEN/Ibn Tofail University, Morocco.

2.5 Ethical Consideration

The study protocol was developed and formally validated by the designated Technical Committee, and subsequently submitted to the Ethics Committee for Biomedical Research of the Faculty of Medicine and Pharmacy, Rabat, Morocco. A favorable ethical opinion was formally obtained on 23 February 2017, authorizing the conduct of the National Nutrition Survey in Morocco. Both oral and written informed consent were obtained from the head of each participating household prior to the commencement of data collection. All participation was entirely voluntary, and the confidentiality and anonymity of all collected data were strictly maintained throughout all phases of the study in accordance with applicable ethical standards.

2.6 Statistical Analysis

All statistical analysis were performed using the Statistical Package for the Social Sciences (SPSS, Version 25.0; IBM Corp., Armonk, NY, USA). Descriptive statistics were employed to characterize the sociodemographic profile of the study population. Continuous variables are presented as means ± standard deviations (SD), whilst categorical variables are expressed as frequencies and percentages with corresponding 95% confidence intervals (CI). All statistical tests were two-tailed, and a p-value of < 0.05 was considered statistically significant. Data are presented as adjusted means or association measures accompanied by their corresponding 95% confidence intervals.

3 Results

3.1 Households Flow and Sample Characteristics for the Iodine Content Analysis

Of the 3,118 households that completed the surrey questionnaires and provided salt samples, a total of 1,963 were retained for laboratory analysis, constituting the final analytical sample. The exclusion of 1,155 households (37%) prior to laboratory analysis was attributable to the following reasons: 262 samples were rejected on account of contamination — principally by ambient humidity, insoluble particulate matter including dust and sand; 788 samples were deemed invalid owing to insufficient volume (< 10 g, below the minimum volume recommended for iodometric titration) (WHO/UNICEF/ICCIDD, 2008); and 105 samples were excluded due to lost or illegible sample identification labels. The participant flow and sample attrition are summarized in Figure 1.

Analysis of the residential distribution of the 1,963 retained households indicated that the majority — 64% (95% CI: 62.3%–66.5%) — resided in urban areas. With respect to socioeconomic status, as assessed by the composite well-being index, a substantial proportion of surveyed households were concentrated in the first and second well-being tertiles, accounting for 34.3% (95% CI: 32.2%–36.4%) and 34.1% (95% CI: 32.0%–36.2%) of the sample, respectively. Regarding salt procurement practices, 73.8% (95% CI: 71.8%–75.8%) of households procure their salt from local traders, whilst only 19.2% (95% CI: 17.5%–20.9%) acquired their table salt from retail markets (Table 1).

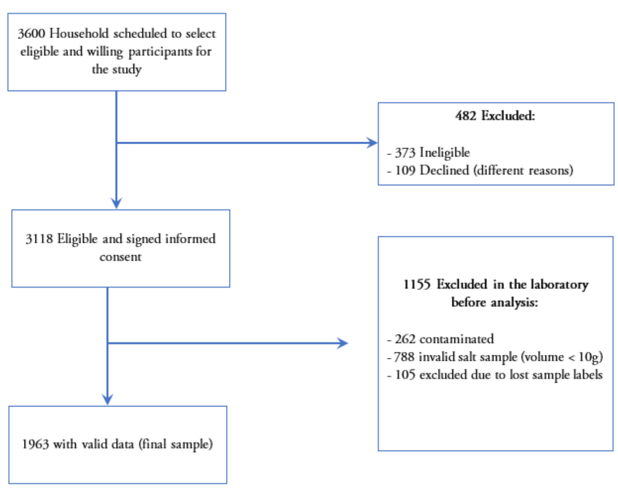

Figure 1. Flow Chart, Iodine Content Analysis of Salt Study

Table 1. General Characteristics of Surveyed Households

	Number of households surveyed	Number of salt samples analyzed	Percentage of salt samples analyzed (%)	%CI
Area of residence				
Urban	1,993	1,265	64.4	62.3–66.5
Rural	1,125	698	35.6	33.5–37.7
Geographical origin				
Zone 1	924	582	29.6	27.6–31.6
Zone 2	1,081	681	34.7	32.6–36.8
Zone 3	752	473	24.1	22.2–26.0
Zone 4	361	227	11.6	10.2–13.0
Type of used salt				
Packaged salt	2,761	1,894	96.5	95.7–97.3
Bulk salt / kg	266	9	0.5	0.2–0.8
Both	91	60	3.0	2.2–3.8
Well-being tertile				
1st tertile	1,143	674	34.3	32.2–36.4
2nd tertile	1,020	670	34.1	32.0–36.2
3rd tertile	955	619	31.6	29.5–33.7
Places of purchase				
Supermarket/ Superette	152	94	4.8	3.9–5.7
Local shopkeeper	2,116	1,449	73.8	71.8–75.8
Market	531	378	19.2	17.5–20.9
Street vendor	14	12	0.7	0.3–1.1
Others	37	30	1.5	1.0–2.0

*CI: confidence interval, * The percentage is taken from the analysis of 1963 salt samples.*

The geographical distribution of surveyed households across the four defined zones was as follows: Zone 2 (Rabat-Salé-Kénitra and Casablanca-Settat) accounted for the largest proportion at 34.7% (95% CI: 32.6%–36.8%), followed by Zone 1 (Tanger-Tétouan-Al Hoceima; Oriental; Fès-Meknès) at 29.6% (95% CI: 27.6%–31.6%), Zone 3 (Béni Mellal-Khénifra; Drâa-Tafilalet; Marrakech-Safi) at 24.1% (95% CI: 22.2%–26.0%), and Zone 4 (Souss-Massa; Guelmim-Oued Noun; Laâyoune-Sakia El Hamra; Dakhla-Oued Eddahab) at 11.6% (95% CI: 10.2%–13.0%).

Analysis of salt packaging type by socioeconomic tertile revealed that 94.6% of households in the third well-being tertile consumed packaged salt, compared with 92.5% and 80.0% in the second and first tertiles, respectively. A statistically significant difference in packaged salt consumption was observed across well-being tertiles (p < 0.0001) (Table 2).

Examination of salt packaging labels collected from surveyed households demonstrated that 96.2% of households consumed salt bearing the "*iodized salt*" logo (Table 3). Consumption of salt labelled with the logo did not differ significantly between urban and rural areas of residence (p = 0.180). Similarly, no statistically significant difference in logo-labelled salt consumption was observed across well-being tertiles (p = 0.158).

3.2 Household Awareness of the *"Iodized Salt"* Logo

Assessment of household knowledge regarding the *"iodised salt"* logo was conducted among all 3,118 households that completed the survey questionnaire. The findings revealed a markedly low level of awareness, with the majority of households demonstrating no familiarity with the logo. As presented in Table 4, 71.0% of surveyed households were unaware of the "*iodized salt*" logos at the time of the survey.

Household awareness of the logo was found to be significantly associated with socioeconomic status, as measured by the well-being tertile. Households in the first (lowest) well-being tertile demonstrated significantly lower awareness of the *"iodised salt"* logo compared with those in higher tertiles (p < 0.0001).

3.3 Iodine Content of Collected Dietary Salt Samples

A total of 1,963 deitary salt samples collected from surveyed households across Morocco were analyzed for iodine content. The iodine content of individual samples ranged widely from 0.00 to 77.0 ppm. The overall median iodine content across the 1,963 samples was 7.40 ppm (95% CI: 7.4–8.0 ppm).

Table 2. Distribution of Salt Types Consumed by Environment and Well-Being Tertile

	N	Salt consumption						p-value
		Packaged salt		Bulk salt / kg		Both		
		(%)	CI (95%)	(%)	CI (95%)	(%)	CI (95%)	
Area of residence								
Urban	1993	93.3	[92.2 – 94.3]	5.4	[4.5–6.5]	1.2	[0.9–1.8]	
Rural	1125	79.8	[77.3 – 82.3]	14.0	[11.9–16.3]	6.2	[4.8–7.8]	< 0.0001
Well-being tertile								
1st tertile	1143	80.0	[77.4 – 82.3]	15.1	[13.1–17.5]	4.9	[3.7–6.3]	
2nd tertile	1020	92.5	[90.9 – 94.1]	5.1	[3.9–6.6]	2.4	[1.5–3.4]	< 0.0001
3rd tertile	955	94.6	[93.1 – 95.9]	4.1	[3.1–5.5]	1.2	[0.7–2.1]	
Total	3118	88.9	[87.9 – 90.1]	8.1	[7.2–9.1]	2.8	[2.3–3.4]	

Note: CI: confidence interval, *The percentage is based on 3,118 households that completed the questionnaire.

Table 3. Distribution of Households by Consumption of Dietary Salt Bearing the "*iodized salt*" Logo, By Area of Residence and Well-Being Tertile

	N	Salt with packaging logo		p-value
		(%)	CI (95%)	
Area of residence				
Urban	955	95.8	[94.3–96.9]	0.180
Rural	517	97.1	[95.4–98.3]	
Well-being tertile				
1st tertile	512	97.1	[95.3–98.3]	
2nd tertile	474	96.6	[94.7–98]	0.158
3rd tertile	486	94.9	[92.6–96.6]	
Total	1472	96.2	[95.1–97.1]	

Table 4. Distribution of Households According to Level of Knowledge of the "*iodized salt*" Logo by Environment and Well-Being Tertile

	N	% of households aware of iodized salt		p-value
		(%)	CI (95%)	
Area of residence				
Urban	1993	30.6	[28.6–32.6]	
Rural	1125	25.7	[22.9–28.8]	0.127
Well-being tertile				
1st tertile	1143	23.9	[21.2–26.8]	
2nd tertile	1020	28.5	[25.8–31.4]	< 0.0001
3rd tertile	955	34.5	[31.5–37.4]	
Total	3118	28.8	[27.5–30.9]	

The distribution of households according to iodine content categories revealed that 25.7% (95% CI: 23.8%–27.6%) consumed non-iodized salt (< 5 ppm), whilst 74.3% (95% CI: 72.4%–76.2%) consumed either inadequately or adequately iodised salt. More specifically, only 7.5% (95% CI: 6.4%–8.7%) of the surveyed households consumed adequately iodized salt (15–40 ppm); 65.6% (95% CI: 63.5%–67.7%) consumed inadequately iodized (5–14.9 ppm); 25.7% (95% CI: 23.8%–27.6%) consumed non-iodized salt (< 5 ppm); and 1.2% (95% CI: 0.8%–1.8%) consumed over-iodized (> 40 ppm) (Figure 2).

With respect to area of residence, the median iodine content of salt samples collected from rural households was 7.4 ppm (95% CI: 7.4–8.5 ppm), whilst that of urban households was 7.8 ppm (95% CI: 7.5–8.9 ppm) (Figure 3). No statistically significant association was identified between the iodine content category of dietary salt and area of residence ($p = 0.915$). Therefore, only 8.0% of urban and 6.4% of rural households consumed adequately iodised salt, with no meaningful urban–rural differential in iodine adequacy.

Regarding geographical zone, salt samples from Zone 1 exhibited the highest iodine content at 7.4 ppm (95% CI: 7.2–8.4 ppm), whilst samples from Zones 2, 3, and 4 recorded a median iodine content of 6.3 ppm (Figure 4). No statistically significant association was identified between the distribution of households across iodine content categories and geographical zone of residence ($p = 0.58$).

Analysis by socioeconomic tertile revealed that 68% of households in the first (lowest) well-being tertile consumed

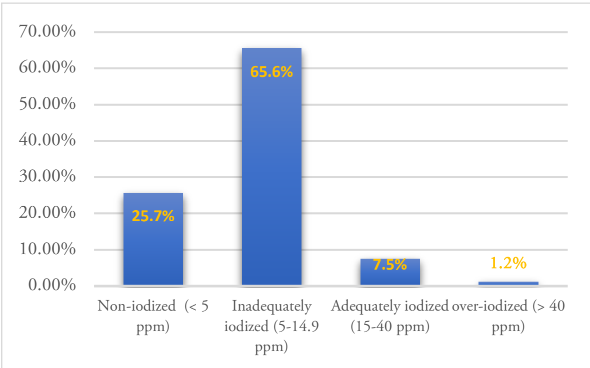

Figure 2. Distribution of Iodine Content in Salt from Collected Households

inadequately iodized salt (5–14.9 ppm), whilst 7.8% of

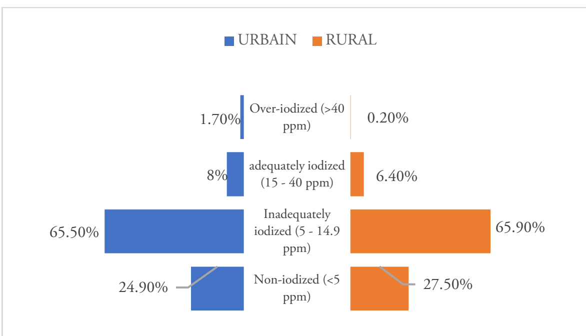

Figure 3. Distribution of Iodine Content in Salt by Area of Residence

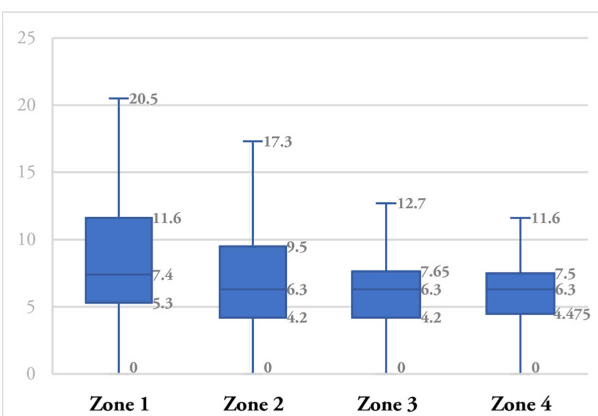

Figure 4. Distribution of Median Iodine Content by Geographical Area

households in the third (highest) well-being tertile consumed adequately iodized salt — a proportion significantly greater than that observed in the lower tertiles ($p < 0.0001$) (Figure 5).

With respect to the reliability of the *"iodised salt"* logo as an indicator of actual iodine content, the results reveal a concerning discordance between labelling and measured iodine adequacy. Despite the near-universal consumption of logo-labelled salt (96.2%), 26.2% of households consuming salt bearing the *"iodised salt"* logo were found to actually consume non-iodised salt (< 5 ppm), compared with 31.4% of households consuming salt without the logo. Furthermore, 64.9% of households using logo-labelled salt consumed salt with insufficient iodine content (5–14.9 ppm), compared with 50.4% of households using unlabelled salt salt (Figure 5).

Regarding the point of salt purchase, analysis of iodine content by procurement source revealed that adequate iodisation was most prevalent among households purchasing salt from supermarkets (12.1%), compared with households purchasing from local traders (7.1%). No adequately iodised salt was recorded among households obtaining salt from street vendors (Figure 5).

4 Discussion

Salt iodization has been formally recommended by the WHO as the most effective and sustainable public health intervention, for the reduction of iodine deficiency disorders (IDD), operating through the fortification of food-grade salt with iodine to increase population-level iodine intake (WHO, 2007; Zimmermann, 2008). In alignment with these recommendations, more than 70% of the global population currently consume iodine-fortified salt, which is universally recognized as the principal dietary source of iodine at the population level (IGN, 2023).

In Morocco, the USI through strategy was formally introduced in 1995 through mandatory iodine fortification of all table salt, initially at a target concentration of 80±10 mg iodine/kg, subsequently revised to 15–40 mg iodine/kg in 2009 (WHO, 2009).

The present study was conducted 25 years following the implementation of this national USI policy and constitutes the first nationwide household-level survey of dietary salt iodization levels in Morocco. It was carried out as an integral component of the National Nutrition Survey 2019–2020, through which salt samples were collected from 3,118 households; of these, 1963 samples fulfilled the quality criteria for iodometric analysis. Furthermore, the present study is designed to be complementary to existing biological iodine status investigations: whilst El Ammari *et al.* (2021) and Rami *et al.* (2022) documented

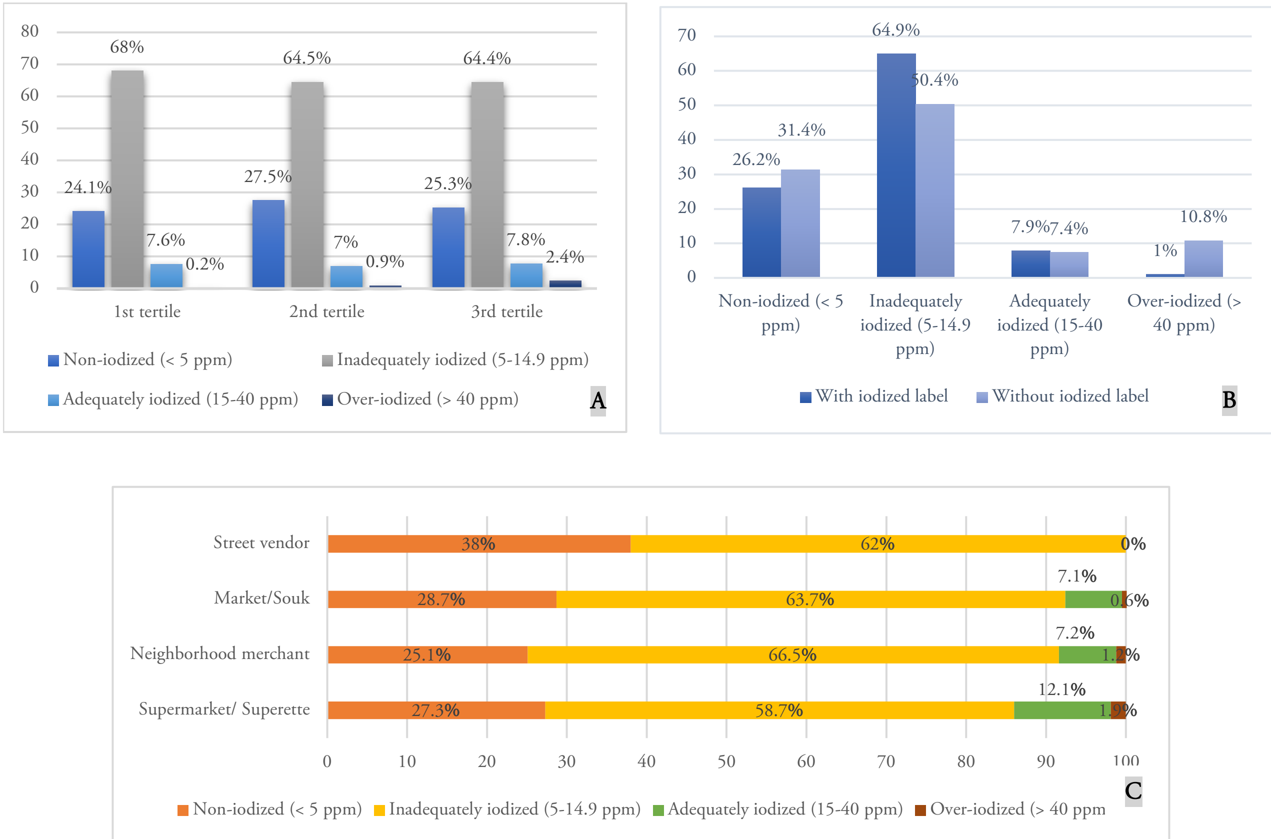

Figure 5. Distribution of Iodine Content by Well-Being Tertile (A), Iodine Logo (B) and by Place of Purchase (C)

persistent iodine deficiency at the population level, the present investigation examines a fundamental upstream determinant — namely, the failure of the salt supply chain to consistently deliver adequately iodized salt to Moroccan households.

The principal finding of this study — a median iodine concentration of 7.40 ppm (95% CI: 7.4–8.0 ppm) in household salt samples — is markedly below the WHO-recommended minimum adequacy threshold of 15 mg/kg, indicating a severe and widespread deficiency in the iodine content of salt consumed at the household level. The distribution of samples by iodine content category further underscores the gravity of this situation: only 7.5% (95% CI: 6.4%–8.7%) of surveyed households consumed adequately iodized salt (15 – 40 ppm); whilst 65.6% (95% CI: 63.5–67.7) consumed inadequately iodized salt (5–14.9 ppm); 25.7% (95% CI: 23.8–27.6) consumed non-iodized salt (< 5 ppm); and 1.2% (95% CI: 0.8–1.8) consumed over-iodized salt (> 40 ppm).

These findings are consistent with the results of several prior regional and national investigations conducted in Morocco. A survey carried out in 1998 in the Rabat-Kénitra region reported that adequately iodized salt accounted for only 9.8% of all salt analyzed, with merely 1.8% of samples complying with the applicable regulatory standard (Zahidi *et al.*, 2002). A subsequent study achieved in 2015 revealed that only 3.8% of companies marketing iodized salt held a valid health authorization, and that the date of manufacture and expiration was indicated on only 8 of 164 analyzed samples, despite being a mandatory labelling requirement under Moroccan standards (Zahidi *et al.*, 2016). A study conducted in the province of Larache in 2011 reported that 90% of urinary iodine measurements were below the normal range, and that only 15% of the salt analyzed was iodized, with none of the samples complying with the applicable Moroccan standard (Bousliman *et al.*, 2011). An earlier investigation by Zahidi *et al.* (2016) assessing the distribution and fortification level of iodized salt in Moroccan households highlighted that only approximately one quarter of participating households consumed iodized salt, of which only approximately 20 samples were found to be adequately fortified. Considered together, these findings demonstrate that the inadequate iodization of household salt has been a persistent and recurrent deficiency in the Moroccan salt supply chain for several decades, predating the present survey.

As a consequence of these persistent supply chain failures, Morocco remained classified as a country in which ID constitutes a significant public health problem as late as 2007, alongside 47 other nations (IGN, 2015). According to a 2013 publication by the Iodine Global Network (IGN), Morocco was among the countries in which ID remained a major public health challenge. with ID constituting a substantial burden in 11 African countries including Morocco (Pearce *et al.*, 2013).

The inadequate iodine content of salt distributed on the Moroccan market is attributable to several interrelated structural deficiencies within the national salt industry. The sector is characterized by fragmented organization, with numerous small-scale producers failing to iodize their salt at all or failing to comply with recommended iodization levels. This situation is compounded by insufficient official regulatory oversight, a substantial informal sector operating without traceability of salt origin, and the simultaneous coexistence of iodized and non-iodized salt products across retail channels. Additionally, the Moroccan salt market is characterized by the presence of imported salts — including those introduced through informal channels — whose compliance with the national iodization standards of 15–40 ppm cannot be consistently guaranteed.

The process of market globalization has further complicated regulatory enforcement by expanding the range and origin of salt products available for retail distribution. These structural factors collectively explain the alarming compliance rates documented in the present study and underscore the imperative to substantially strengthen regulatory monitoring at all levels of the salt supply chain — from production through to retail distribution — and to ensure that the salt industry possesses both the technical capacity and the regulatory incentive to consistently produce adequately iodized salt. In this regard, the experience of Ethiopia is instructive: following the introduction of legislation mandating the iodization of all salt intended for human consumption in February 2011, the proportion of households with access to adequately iodized salt increased from approximately 20% prior to 2011 to over 50% by 2012 (Asfaw *et al.*, 2022).

A further dimension of concern identified in the present study relates to the labelling of edible salt. Analysis of packaging data revealed that the majority of salt samples on the Moroccan market do not indicate the iodine concentration on the label, notwithstanding the regulatory requirement that all salt marketed on Moroccan territory bear the designation *"iodized salt"* along with its iodine concentration on the packaging. These findings confirm that a significant proportion of salt producers are not operating in compliance with applicable labelling regulations, and that the *"iodized salt"* logo cannot be considered a reliable indicator of actual iodine content. Specifically, 26.2% of households consuming logo-labelled salt were found to actually consume non-iodized salt (< 5 ppm), demonstrating a fundamental and concerning discordance between labelling and measured iodine adequacy.

With respect to household awareness of the *"iodized salt"* logo, the findings reveal a markedly low level of consumer knowledge: 71.0% of surveyed households were unaware of the *"iodized salt"* logo. A statistically significant positive association was identified between logo awareness and well-being tertile ($p < 0.0001$), whilst no significant association was observed with area of residence ($p = 0.127$). These findings indicate that as the socioeconomic status and educational level of the household head increase, awareness of the iodized salt logo increases correspondingly. This pattern is consistent with findings from comparable studies conducted in Ethiopia (Girma *et al.*, 2012) and Australia (Charlton *et al.*, 2010). The disparities in awareness across well-being tertiles are likely attributable to differences in educational attainment, exposure to public health communication campaigns, and access to nutritional information. The determinants of regional variation in logo awareness warrant further investigation, as differences in the content, coverage, and reach of nutritional education programs across Moroccan regions may constitute a significant contributing factor.

Regarding the rural–urban differential in iodine adequacy, the present study found no statistically significant difference in median iodine concentrations between urban and rural areas ($p = 0.915$); however, the proportion of households consuming adequately iodized salt (≥ 15 ppm) was significantly higher in urban (8.0%) compared with rural areas (6.4%). This modest difference is partly explained by the higher utilization of bulk salt in rural areas (14%), a product category that is predominantly non-iodized and is procured through informal, unregulated channels, thereby precluding quality assurance or regulatory compliance monitoring.

Contextualization of the present findings within the longitudinal iodine status data for Morocco reveals a complex and contradictory picture. Prior to the adoption of USI in 1995, a national survey conducted in 1993 (Chaouki *et al.*, 1993) reported a median urinary iodine concentration (mUIC) of 86 μg/L among school-aged children, indicative of moderate ID. Nearly three decades later, El Ammari *et al.* (2021) reported a national mUIC of 117.4 µg/L (95% CI: 110.2–123.3 µg/L) among 1,043 Moroccan children aged 6–12 years, a value meeting the WHO threshold for iodine sufficiency at the national level (mUIC ≥ 100 µg/L), suggesting an overall improvement in population iodine status since the introduction of USI. However, this apparently favorable national aggregate conceals significant subnational disparities: 21.6% of children exhibited a mUIC below 50 µg/L — exceeding the WHO-recommended upper limit of 20% — and Zone 3 (the central, high-altitude, non-coastal zone) remained iodine-deficient with a mUIC of 89.2 µg/L ($p < 0.004$) (El Ammari *et al.,* 2021). Furthermore, Rami *et al.* (2022), in a study of 1,652 Moroccan women of childbearing age (15 – 49 years), reported a mUIC of 71.3 μg/L, indicates mild ID in this particularly vulnerable population group. Women of childbearing age are especially susceptible to the consequences of IDD, which may manifest as goiter, pregnancy complications including spontaneous abortion and stillbirths, and neurocognitive impairments in neonates and infants.

The present study complements these biological investigations by elucidating a fundamental supply-side determinant of these observed deficiencies: the inadequate quality of iodized salt available within the Moroccan market. Given that only 7.5% of the salt consumed by surveyed household met the recommended iodization standard, combined with the demonstrated unreliability of the “iodized salt” logo, provides a compelling mechanistic explanation for the persistent iodine deficiency documented among Moroccan children and women of reproductive age. The discordance between the presence of logo and actual iodine adequacy directly reflects supply chain failures at multiple levels of the salt production and distribution system. However, it is acknowledged that directly connecting household salt iodine content to biological iodine status would substantially strengthen the interpretation of these findings. Future studies are therefore strongly recommended that to collect both salt iodine content and urinary iodine concentration data from the same participating households, enabling a more robust assessment of the relationship between salt quality and population iodine nutritional status.

The observation that, despite 96.2% of households reporting the utilization of logo labelled "*iodized salt*", only 7.5% of the salt consumed was found to be adequately iodized in 2019 – 2020 represents a paradox of considerable public health significance. This discordance suggests that any improvement in national urinary iodine concentrations may be fragile and potentially attributable to dietary iodine sources other than salt — such as seafood, dairy products, and iodine-containing water — rather than to the successful implementation of USI. The parallel observation that salt procured from street vendors was uniformly non-iodized reinforces the critical importance of informal distribution channels as a structural risk factor for inadequate household iodine intake.

The intricate structure of Morocco's salt industry poses significant challenges in enforcing health regulations and ensuring quality control. The Moroccan salt sector is distinguished by the coexistence of industrial and artisanal producers. It is also characterized by the presence of imported salts that may not comply with national standards, and by challenges in regulating formal and informal supply chains. This complexity arises from the diverse origins of salt, which can be domestic or imported, and the wide range of products available on the market. The coexistence of industrial and artisanal producers gives rise to disparities in compliance with iodization standards. Furthermore, the process of market globalization has resulted in the introduction of imported salts whose compliance with national standards (15–40 ppm) cannot always be guaranteed. Moreover, the regulation of supply chains remains a challenging endeavor, irrespective of the point of sale (whether formal or informal). These factors partly explain our alarming results and highlight the need to strengthen surveillance at all levels. Nevertheless, it is recommended that future research focus on the salt supply chain – from production to consumption – including the origin and quality of imported salts.

Within the North African regional context, the compliance rate documented in the present study (7.5%) is of particular concern. In Tunisia, Doggui *et al.* (2016) reported that 85.6% of salt samples were adequately iodized, with more than 78% of households consuming iodized salt. In Algeria, Hannous *et al.* (2025) documented a median iodine content of 17.5 mg/kg, with only 19.2% of samples meeting the required standard, 73.6% classified as insufficiently iodized, and 7.1% are excessively iodized. A further Algerian study (Zergui *et al.*, 2023) revealed that only three of the products analyzed met WHO iodization standards, whilst 26 samples contained no detectable iodine. The Moroccan compliance rate of 7.5% is markedly lower than that of Algeria (19.2%) and dramatically below the 85.6% recorded in Tunisia, underscoring the pressing need for comprehensive harmonization and substantial enhancement of quality control mechanisms across the Moroccan salt supply chain.

The national program for the control IDD can achieve its intended public health objectives only if a robust system of internal monitoring and external quality control is established, and if additional evidence-based operational strategies are developed and implemented. Public health authorities and salt producers must operate in close partnership, with targeted support provided to small-scale and artisanal producers to facilitate their formation of cooperatives and their access to technical resources, including potassium iodate and standardized iodine test kits. Regulatory controls and monitoring of edible salt must be intensified, with particular emphasis on prohibiting the unregulated sale of bulk, non-iodized salt in traditional markets and rural areas. Enhanced regulatory oversight by the National Office for the Safety of Food Products (ONSSA) would enable more responsive program adjustment and more rigorous evaluation of intervention impact. For populations with limited access to adequately iodized salt — particularly in the most severely affected geographic zones — health authorities should consider the implementation of complementary iodine supplementation strategies, including iodized oil, as a transitional measure alongside the strengthening of the salt iodization program Regular population-level monitoring of iodine nutritional status through urinary iodine concentration surveys should additionally be institutionalized as a core component of the national IDD control program.

Beyond the issues related to compliance with iodization standards and the reliability of logos highlighted in this study, the findings of the present study must furthermore be situated within the broader global public health debate on the potential tension between salt iodization and sodium reduction strategies for the prevention of hypertension and cardiovascular disease. As population-level salt intake declines in response to public health campaigns and food reformulation initiatives, it may become necessary to proportionally adjust the iodine concentration in salt to maintain adequate iodine status. Future research in Morocco should therefore simultaneously assess dietary salt intake levels, the prevalence of hypertension, and urinary iodine concentrations to determine whether current iodization standards of 15 – 40 ppm remain nutritionally adequate in the context of evolving Moroccan dietary patterns.

Several important limitations of this study must be acknowledged. First, the cross-sectional study design precludes the establishment of causal inferences regarding the relationship between household characteristics and salt iodization status. Second, urinary iodine concentrations were not measured in the study participants, which would have permitted a direct assessment of the impact of salt iodine content on the nutritional iodine status of the surveyed population — a significant gap that limits the interpretive scope of the findings. Third, a substantial sample attrition of 37% occurred, with only 1,963 of the 3,118 initially recruited ultimately eligible for iodine analysis, attributable to contaminated samples, insufficient sample volume, and lost sample labels; this degree of attrition may have introduced selection bias and should be considered when interpreting the representativeness of the results. Fourth, detailed dietary data — including the frequency of salt addition during food preparation and at the table, the consumption of processed foods, and the utilization of alternative dietary iodine sources such as seafood and dairy products — were not systematically collected, limiting the comprehensiveness of the assessment of total dietary iodine intake. Future research should address these limitations through the incorporation of urinary iodine measurements, comprehensive dietary assessment methodologies and longitudinal designs capable of capturing temporal trends in salt iodization compliance and population iodine status.

5 Conclusions

Twenty-five years following the formal adoption of Morocco's Universal Salt Iodization program, the findings of the present study demonstrate that the objective of effective, equitable, and widespread salt iodization remains far from achieved at the household level. Despite the near-universal self-reported use of salt bearing the "*iodized salt*" logo (96.2%), only a minor proportion of the salt actually consumed by Moroccan households (7.5%) met the internationally recommended iodine adequacy threshold of 15–40 ppm, with a national median iodine concentration of 7.40 ppm — well below the minimum standard. The "*iodized salt*" logo has been demonstrated to be an unreliable indicator of actual iodine content, and the widespread use of bulk salt, non-iodized salt — particularly in rural areas — constitutes a significant and persistent structural obstacle to the achievement of universal iodine adequacy. These findings expose critical and systemic failures in quality control, supply chain regulation, iodization compliance monitoring, consumer awareness, and salt storage conditions. To transform Morocco's USI program into a genuine and sustainable public health success, urgent and concerted action is required across multiple levels: rigorous and comprehensive quality control mechanisms must be implemented throughout the salt supply chain; storage conditions and product traceability must be improved; regulatory enforcement must be substantially strengthened; and targeted public awareness and nutritional education campaigns must be developed and disseminated, with particular attention to the most socioeconomically vulnerable and geographically isolated populations.

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