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INVENTORY ON THE VALORIZATION OF THE RESIDUES DERIVING FROM THE ORANGES (*CITRUS SINENSIS* L.) CONSUMPTION IN CÔTE D'IVOIRE

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ABSTRACT

This investigation at field performed about the oranges fruits consumption aimed to assess ways of valorization for the residues of these fruits in Côte d'Ivoire. The investigation was achieved from oranges consumers in ten communes of the district of Abidjan, between March and April 2016. Questionnaires cards were drawn for collecting information regarding oranges consumers' profile, oranges consumption factors, oranges by-products and their valorization. Thus, the most oranges consumers are adult people over 40 years of age (64.01%) and rather educated (65.7%). The oranges are consumed for properties in vitamin C (51%) and digestive virtues (37%). The colored peels (70%), the whitish membranous mesocarp (20%), the seeds (1%), and even the pulp membrane (4%) are generally parts rejected as consumption wastes. Yet, these residues are known to be valorizable according to 65% consumers. Their valorizations ways deal with food additives (73%), food coloring (25%), soaps and ointments (60%), and detergent products (32%). They're also supposed to be useful for health (37%), agronomy (70%), and bio-combustible (26%). Accounting the consumers positive interests for the oranges residues, various technological processes could be applied to these consumption by-products for providing more value added to the oranges production.

KEYWORDS: Valorization, residues of consumption, *Citrus sinensis*, Côte d'Ivoire.

INTRODUCTION

The orange tree (*Citrus sinensis* L.) is a fruit plant belonging to the family of Rutaceae and originating from the South-Eastern Asia.[1] It grows from various soils and climates: it is cultivated on primary and secondary soils in forest lands as well as the tertiary and quaternary soils from semi-arid and arid zones in the savannas and sandy regions. Thus, the orange plant is met in most of the tropical and subtropical countries. Its main uses are deriving from the production of *Citrus* fruits commonly known as oranges.[2] The world production of oranges is estimated at 66,400,000 tons per year from which Brazil is the lead country.[3] In Côte d'Ivoire, the orange groves account 500 ha of area with a yearly production of 500,000 tons of fruits.[4]

The oranges fruits are widely consumed over the world in several places and occasions. They are taken as dessert after meals, but are also tasted regardless of the places. The oranges are generally enjoyed for their good organoleptic, nutritive, and dietetic properties and are consumed fresh or processed into juice.[5,2] These restrictive uses therefore induce the by-production of important volume of oranges residues consisted of peels and seeds.[6] The peels represent the pericarp layer enclosing various pigments, but the whitish mesocarp layer underneath is also joined.[7] Without any interests, the residues of oranges consumption are usually rejected and even represent a source of environmental pollution when rotting. Yet, different works reveal numerous technologies for these consumption by-products in agro-food, cosmetic, health, and bio-combustible industries thanks to their great content in functional compounds such as essences, glucides, vitamins, and minerals.[8,9] Indeed, the oranges consumption by-products are highly fermentable because of the significant content in carbohydrates and water.[10] In addition, Bampidis and Robinson [11] reported on the food abilities of the oranges residues dealing with the digestive compounds that they enclose. Also, the oranges residues represent important source of odored substances and essences valued at 0.6 to 1%.[12] Besides, the oranges peels are richer in other active bio-molecules as C vitamin, phenolic compounds, and food fibers.[13,14] Thus, they are used fresh or dried and powdered for flavoring teas, traditional dishes, and cakes. Pectins extracted from the oranges peels fibers are

used for dietetics foods processing thanks to their thickening, texturing, jelling, and stabilizing traits.[15] The *Citrus* residues extracts are also valued in preparation cosmetics as soaps and perfumes, and are processed for chemical and biological organic solvents thanks to their higher content in limonene.[16] Moreover, the oranges peels extracts contain biomolecules as linalol and citral for antibacterial medicines against *Campylobacter jejuni* and *Escherichia coli*. So, the anti-fungal effect of oranges essences can be alternatives to synthetic fungicide.[17]

Other uses of the oranges residues deal with the production of paper dough or as raw material for the cellulose derivatives.[18] Byrne *et al.*[19] showed that the oranges by-products can support production of biodegradable plastic papers through biochemical reactions as polymerization of peels' limonene and carbon dioxide.

In Côte d'Ivoire, except for the reports of Assa *et al*.[8] on physicochemical parameters of the oranges peels, there are scanty works about the oranges residues which valorization therefore remains inexistent. Besides, Lagou *et al.*[20] revealed significant oranges imports from neighboring countries due to the deficiency of the local production to fit the consumers' demand. In this case, the valorization of the residues deriving from the oranges consumption could provide additional income to the local *Citrus* fruits stakeholders. However, such a perspective requires preliminary inventory of the main uses possibilities for these fruits consumption by-products. The current investigation targets the consumption of oranges and the valorization of their residues in order to improve the profitability of the oranges production.

MATERIAL AND METHODS

Material and experimental design

The survey is an investigation at field performed from the oranges consumers in 10 communes of the Autonomous District of Abidjan, Côte d'Ivoire. They communes were namely Abobo, Adjame, Attecoube, Cocody, Marcory, Koumasi, Plateau, Port-Bouët, Treichville, and Yopougon. Questionnaire cards were drawn beforehand and then charted during the investigation implementation.

Methods

Investigation implementation

The investigation has been achieved during two (2) months, from March to April 2016. Ten (10) consumers were interviewed per commune regardless of their gender and age and social condition, leading to an overall size of 100 persons investigated for the study. The data was collected through the questionnaire cards filled from the oranges consumers. The requested information targeted the consumers' profile, the criteria of oranges consumption, the oranges parts known to be consumed or non-consumed, and the valorization perspectives of the oranges consumption by-products.

Statistical analysis

The data collected were statistically analyzed using Statistica software (STATISTICA 7.1). The statistical treatment consisted in a non- parametric Chi square (X^2) test for comparison of rating percentages recorded for each parameter. The significance level was considered at 5%.

RESULTS

Profile of the oranges consumers

Figure 1 and table 1 display the data regarding the gender, age, nationality, and level of literacy of the oranges consumers investigated.

The oranges fruits are as enjoyed by men as women, with respective rate of 41% and 59%, without any statistical difference ($p = 0.085$). But the other parameters differentiate ($p<0.001$) the individuals investigated. Thus, the adult individuals are the major oranges consumers, among which people between 41 and 50 years are more represented (64.01%), against less than 10% for consumers below 20 years and over 50 years (figure 1). The oranges consumers are mainly Ivorian citizens (78%), against 22% of foreigners, especially West African countries originating people. Otherwise, 65.7% investigated consumers display good education level while 10.1% are fairly educated or even illiterate (table 1).

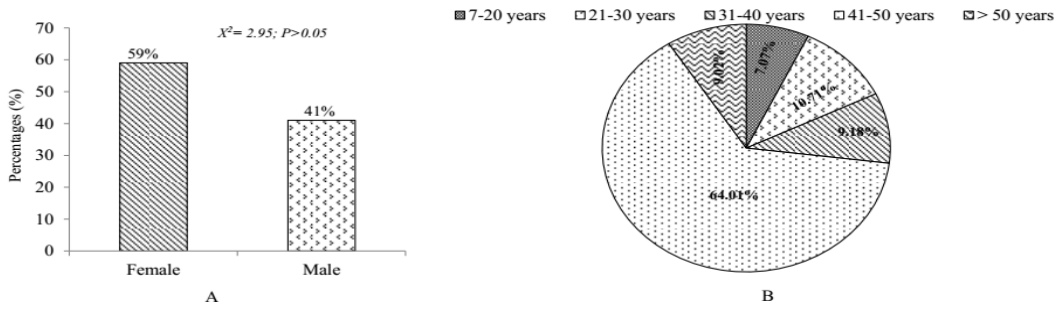

Figure 1. Rates of gender (A) and ages groups of the oranges consumers investigated. *X^2, Chi square statistical value; P, statistical probability value.*

Main data of oranges consumption

From 65% investigated people, the oranges are consumed at frequency of once a day. But 34% consumers rated oranges intake of twice a day and only 1% among them have oranges consumption for 3 times a day, as shown at figure 1A. During each day, only one orange is consumed in 59% cases, against 11% to 14% between 2 and 4 oranges, and only 3% for 5 oranges (figure 1B).

Table 1: Nationality and level of literacy of the oranges consumers investigated.

Parameters	Rating percentages (%)	X^2	P_{-value}
Nationality	Ivorians (78) - West African countries (18) - Others (4)	91.89	<0.001
Education	High (65.7) - Moderate (24.2) - Fair (10.1)	50.02	<0.001

X^2, Chi-square statistical value; P_{-value}, value of statistical probability value

Figure 2 shows the main reasons told by the investigated people for their oranges consumption. Thus, the oranges are generally consumed for their richness in vitamin C and digestive properties according to respective 51% and 37% people. Paradoxically, only 12% consumers do assume taking oranges for nutritional importance.

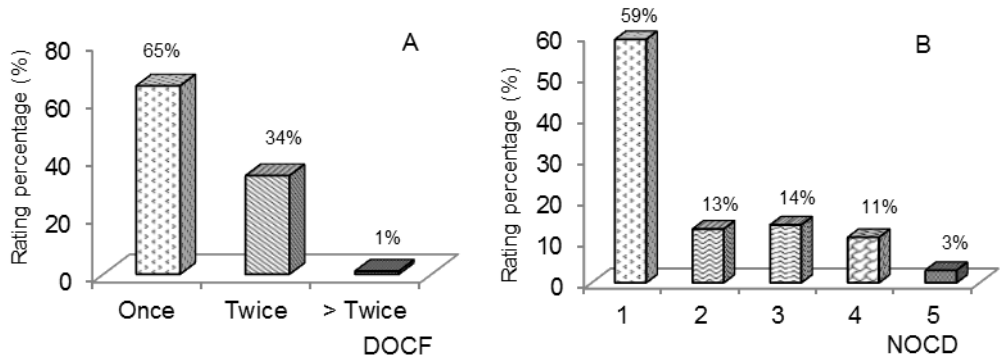

Figure 2: Daily frequency (A) and number (B) of oranges consumed by investigated people *DOCF, daily orange consumption frequency; NOCD, number oranges consumed daily.*

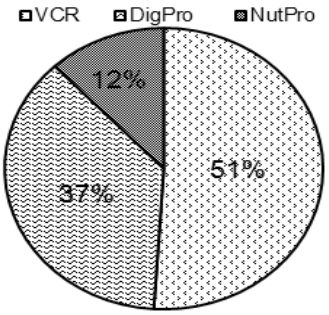

Figure 3: Justifications rated for the oranges consumption *VCR, richness in C vitamin; DigPro, Digestive property; NutPro, Nutritional property.*

Otherwise, in 54% cases, the oranges are consumed only by ingestion of their juice; while 37% people do consume juice as well as the whole fruit pulp (figure 3A). Such fruits parts are mainly consumed for their delicious and appetizing taste (54%) and their aroma (39%), but rarely for their appearance (figure 3B).

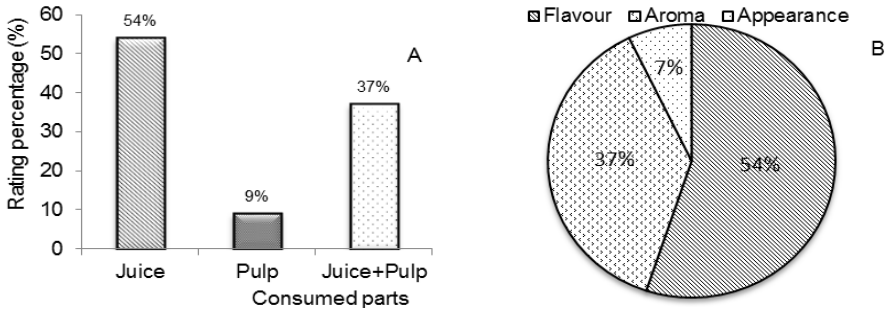

Figure 4: Different oranges parts consumed (A) and main justifications of consumption (B).

Residues resulting from the oranges consumption

Figure 5 reveals the oranges residues deriving from the consumption of fruits juice and pulp, as rated by the consumers investigated. The peels are the most important residues deriving from the oranges consumption (70%), followed by the whitish mesocarp membrane (20%). Sometimes, both peels and whitish membrane are considered as residues (5%). The membranes of pulp slices and the seeds are also oranges residues for 4% and 1% investigated people, respectively (figure 5A). Most of the oranges residues are still thrown as wastes by 58% consumers, whereas 37% answers forecast on their usefulness in livestock feed (figure 5B).

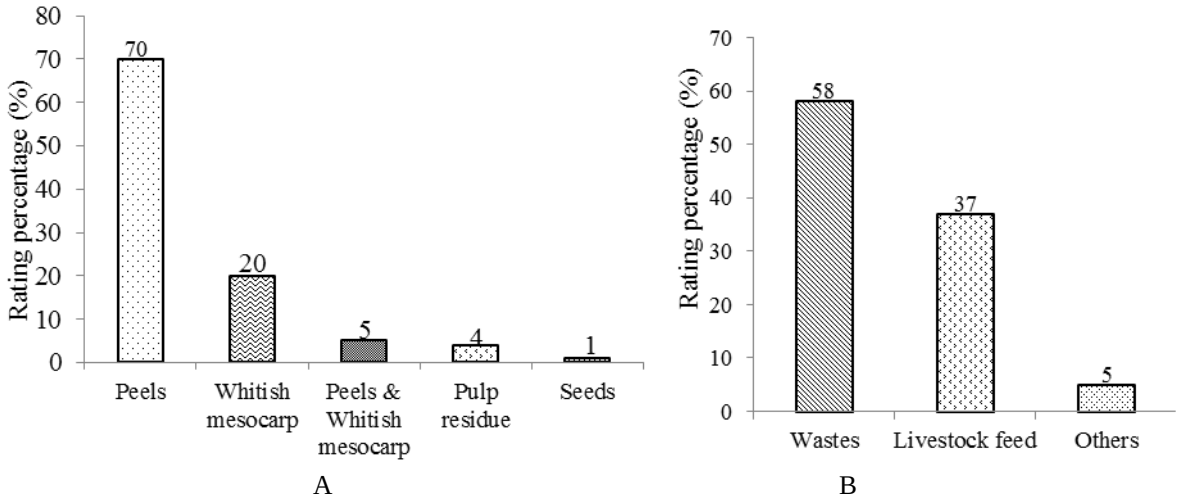

Figure 5: Main oranges residues (A) and their becoming (B) according to the consumers investigated.

Various technological valorization ways of those residues ($p<0.001$) are rated by the consumers. Indeed, people are aware of their food valorizations, especially in uses as food additives and colorants, according to respective 73% and 25% ratings. Even food processing from the residues are mentioned by consumers, namely for essences extraction (75%) and acetic acid production (24%). Other non-food practices are also rated, dealing with cosmetic (60%) and health and well-being (37%) uses. Besides, the oranges residues are supposed to be useful for agro-fertilizers and bio-fuels productions according to 75% and 26% investigated consumers, respectively, and 4% people rated it can even be valued in pharmacological formulations (table 2).

Table 2: Valorization abilities of the oranges residues rated by the consumers investigated.

Ways of uses rated	Proportions (%)	X^2	P_{-value}
Food use	Food additives (73) – Juice colorant (25) – Culinary aroma (2)	77.94	<0.001
	Acetic acid production (24) – Essences extraction (75) – Food processing (1)	85.28	<0.001
Non Food use	Cosmetics (60) – Health and well-being (37) – Others (3)	48.28	<0.001
	Soil fertilizer (70) – Biofuel (26) – Pharmacological products (4)	66.92	<0.001

X^2, Chi-square statistical value; P_{-value}, value of statistical probability value.

DISCUSSION

The orange is as much consumed by women and men in Côte d'Ivoire, especially by the local populations who are the most numerous. The observation agrees with the reports of the USDA[2] indicating that *Citrus* fruits and particularly oranges are of the most consumed fruits over the world. Otherwise, the oranges are more consumed by adult people, mainly of more than 40 years of age. Various reasons could be mentioned for such information. Indeed, the oranges provision is not always accessible to all purses.[20] Also, the oranges are good sources of raw antioxidants allowing the lowering of the blood oxidative stress for avoiding the premature ageing.[21] The nutritious awareness of the oranges is correlated to the good education level of most of consumers according to the investigation. Thanks to their education, the consumers do mention the vitamin and digestive interests resulting from the ingestion of the oranges pulp and juice. In fact, the survey shows that both pulp and juice remain the main food valorization of the oranges, corroborating previous reports of USDA[2] and Bennici *et al.*[22] from which the endocarp is the main edible part of *Citrus* fruits. The consumption of the orange juice is promoted by its delicious flavor providing well-being sense in mouth. The succulent effect is a quality criterion for the fruits' tasting leading to a good salivation and stimulating the appetite. Similar observation was reported by Bauer *et al.*[23] who mentioned moreover that the mature fruit appearance is as enthralling as the flavor.

Oppositely to the endocarp, the oranges epicarp or peels, the whitish membranous mesocarp, and the seeds are rejected as residues during the fruits consumption. Marin *et al.*[6] mentioned that only the third volume of *Citrus* fruits is used during juice production. From the observations reported by Ramful *et al*.[7] the *Citrus* fruits residues are consisted of the peripheral surface, the inner layer, and the seeds. At the first approach, the oranges residues are known as wastes and environmental pollution agents. But, the respondents rated for their uses in livestock feed. Ledesma and Luque[9] also emphasized the practices of the *Citrus* fruits residues in the livestock feeds. Although generally thrown, the current investigation forecasts valorization ways for the oranges residues as mentioned by the consumers. So, the oranges peels can be valued as food additives, ingredients for juices, jam, *etc*., thanks to their significant nutritional virtues, namely for aromas.[24,25,26] The works of Mackeix *et al.*[27] showed that the organoleptic properties of the peels are usable in agro-food industries. Used fresh or dried and ground, the peels are flavoring agents for teas and some traditional dishes and cakes. Wang *et al*.[28] revealed fibers from the oranges residues enabling their use for processing dietaries against constipation.

Moreover, non-food uses of the oranges residues are indicated by the consumers in cosmetic, health, agronomy, and bio-fuels interests. Several people are aware that the essences extracted from the oranges peels and seeds can be incorporated in the cosmetics as soaps and ointments. These feasibilities are in accordance with Lohrasbi *et al*.[16] who showed that the *Citrus* fruits by-products are used as inputs in medicines, soaps, and perfumes processing. Some therapeutical, antiseptical, analgesical, and anti-inflammatory interests of the oranges residues, especially from peels have also been previously reported by authors.[29,30] The works of Assa *et al*.[8] revealed significant amount of mineral elements and glucides in the oranges residues. The mineral parameters could strengthen their agro-industrial use through the production of soil fertilizer; whereas the glucides fermentation could lead to the production of biofuel and biogas according to Pourbafrani et *al.*[31] Numerous ways of technological valorizations of the oranges residues are therefore thinkable.

CONCLUSION

This work is a prospective investigation for the valorization of the oranges consumption by-products in Côte d'Ivoire. From the 3 main parts of the orange fruit, only the endocarp or pulp is consumed for the orange juice. The peels, whitish mesocarp, and even the pulp seeds are usually rejected are wastes and are source of environmental pollution once rotten. However, these residues are highly valorizable, in the agro-food, health, cosmetics, and energizing industries. The search of functional, nutritional, and anti-microbial properties of the oranges residues could help for their use in technological programs in order to increase the value addition of these tropical fruits.

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