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Nutritional Profile of *Pleurotus geesteranus* from Different Harvests

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Authors' contributions

This work was carried out in collaboration among all authors. Author NKCO is the principal investigator of this research. Author NKCO was responsible for the collection of samples and contributed to the chemical analyses. Authors AC and ACK contributed to the analyses and wrote of the manuscript. Author NGA participated in the design of the study. Author YDN was responsible for the formulation of the research question and reviewed the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The purpose of this study was to evaluate the contribution of the mushroom *Pleurotus geesteranus* (*P. geesteranus*) to a good balanced diet. Against the backdrop of three harvests of this mushroom were carried out on the same substrate, this evaluation was made through a physico-chemical analysis according to standard methods and SAIN/LIM scores were calculated using the nutrient profiling system of the French Food Safety Agency. The main information that emerges is that *P. geesteranus* remains of excellent nutritional quality, independently of the harvest. This result is justified by their $SAIN_5 \geq 5$ and $LIM_3 < 7.5$ scores and their classification in the category of foods recommended for health. Also, the different harvests of the mushroom seemed not to have influenced this quality despite the large variations observed in its biochemical composition.

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1. INTRODUCTION

The fruiting body of the mushrooms is a food product highly prized by the living populations in Côte d'Ivoire [1]. This body is used as an accompaniment to sauces as a protein supplement or as a substitute for fish and meat [2]. For these populations, it is a source of nutrients such as the vitamins and minerals Fe, Zn, K, P and Ca [3,4]. In addition, the body of the mushrooms provides them with proteins of high biological value and dietary fiber [5]. Despite its low lipid content, their profile is rich in unsaturated fatty acids (UFAs). These high dietary fiber contents, more precisely in polysaccharides, make this food an asset in the nutritional management of people suffering from metabolic diseases such as obesity and type 2 diabetes [6]. Their richness in phenolic compounds and organic acids could respectively contribute to the fight and management of heart disease and hypertension (hypertension). It is on the strength of these assets that most edible mushrooms offer a nutritional profile that can contribute to achieving nutritional balance. Darmon et al. [7] have shown that edibles mushrooms considered as cooked vegetables are classified among the foods recommended for health according to the SAIN and LIM nutritional profiling system. Nutritional profiling is the classification of foods according to their nutritional quality and their contribution to a balanced diet. In fact, two independent scores characterize the SAIN LIM system. The SAIN score only synthesizes nutrients that are healthy for health (Protein; Fiber; Vitamin C; Calcium; Iron), while the LIM score only presents nutrients to be limited (Saturated fatty acids; Added sugars; Sodium) [8]. This system indicates the expression of the nutritional quality of foods and their place in dietary health measures (MHD).

The availability and accessibility of the *P. geesteranus* mushrooms on Ivorian markets is ensured by growing the mushrooms above ground. This production technique advocates the use of a nutritious substrate (carbon, nitrogen and minerals) that can exclusively cover the needs of the growing mushrooms. However, with a saprophytic way of life, the acquisition of these nutrients by enzymatic means undoubtedly modifies the chemical composition of the growing medium of the mushrooms [9]. This chemical modification of the substrate could influence the nutrient profile (SAIN, LIM) of the mushroom [10,11,12,13] on several crops, especially since these crops are harvested on the same substrate. This is an important agronomic aspect that determines the nutritional quality of the fruiting body of the mushrooms for the consumer [14].

In Côte d'Ivoire, *P. geesteranus* is a mushrooms that occupies an important place in the consumption habits of the population. The mushroom growers who commercialize it, carry out several harvests over a long period, up to two months. As a result, its presence on the consumer's plate raises enormous questions about its nutritional quality and health virtues. Thus, the nutritional profiling of edible mushrooms through the determination of SAIN and LIM markers is an indispensable tool to ensure their ability to contribute to the nutritional balance of the consumer. The objective of this study was to evaluate the nutritional profile of the *P. geesteranus* mushrooms from three harvests on the same substrate.

2. MATERIALS AND METHODS

2.1 Sample Collection

P. geesteranus mushrooms were collected in the FESAAP (Femmes Solidaires pour l'Action et l'Auto-Promotion) mushroom farm located in Dabou, Cote d'Ivoire (5°19'18.9"N 4°23'54.7"W). During the fruiting period, which lasted 60 days, a periodic harvest was carried out at two-day intervals. The mushrooms harvested on the first day (PG1), on the thirtieth day (PG2) and on the sixtieth day (PG3) were selected. The stipe residues from the samples were removed and taken to the laboratory for further analysis.

2.2 Proximal Composition

Fresh mushrooms from each *P. geesteranus* harvest were dried in an oven (Thitec 250, France) at 550°C for 24 hours to determine the total ash content [15]. For further biochemical analyses, the fresh mushrooms were dried at 60°C and crushed using a blender (Bimby mod. 2200, Vorwerk, Wuppertal, Germany). The Kjeldahl method [15] was used to determine crude protein contents from the nitrogen contents (N×6.25) obtained. Continuous extraction was carried out in a Soxhlet apparatus for 8 h using hexane as solvent [15] to determine the crude fat contents. The total carbohydrate content was

determined by difference, i.e. by deducting the mean values of the other parameters which were determined from 100. Therefore, % carbohydrate = 100 - (% moisture + % crude protein + % crude fat + % crude fibre + % ash). The total fiber content of *P. geesteranus* mushroom samples was determined according to Weende's method Multon [16]. The energy value of *P. geesteranus* mushroom powders was calculated by applying the specific coefficients of Atwater and Rosa [17].

2.3 Determination of Crude Polysaccharides

The polysaccharide content was determined using the Yap method and Ng [18].

2.4 Mineral Composition

Minerals, such as calcium, iron and sodium, were analysed after a first washing with water according to the method prescribed by Onwuliri and Anekwe [19] with an atomic absorption spectrophotometer (Pye-Unicam 969, Cambridge, UK).

2.5 Fatty Acid Analysis

The fatty acid content *of P. geesteranus* mushroom samples was determined by analysis of methyl esters of fatty acids in gas chromatography (GC) according to the Association française de normalisation (AFNOR) standard NF ISO 17059 [20].

2.6 Nutritional Profile

The nutritional profile of *P. geesteranus* mushrooms was evaluated using the nutrient profiling system of the French Food Safety Agency based on two scores $SAIN_5$ and LIM_3 [8,21]. For 100 g of mushroom, threshold values were defined for each score, as previously described by Darmon et al. [21]. Based on the SAIN and LIM values and the threshold defined for each score (SAIN threshold ≥ 5 and LIM threshold < 7.5), each food product was classified in one of four possible classes:

- Class 1, $SAIN_5 \geq 5$ and $LIM_3 < 7.5$ (most favorable profile; recommended for health);
- Class 2, $SAIN_5 < 5$ and $LIM_3 < 7.5$ (neutral profile; recommended, to be supplemented with foods of high SAIN);
- Class 3, $SAIN_5 \geq 5$ and $LIM_3 \geq 7.5$ (intermediate profile; recommended, to be consumed occasionally and in small quantities);
- Class 4, $SAIN_5 < 5$ and $LIM_3 \geq 7.5$ (least favourable profile; to be limited, to be consumed exceptionally).

2.7 Statistical Analyses

Statistical analyses were performed with XLSTAT software (Addinosoft Inc.). One-way ANOVA analysis of variance followed by the TUCKEY multiple test with a significant level $\alpha = .05$ were performed in order to compare the nutritional compositions of the mushroom samples

3. RESULTS

3.1 Nutrient Composition of *P. geesteranus* at Different Harvests

Table 1 shows the nutrient compositions of *P. geesteranus* at different harvests. The dry fruit body of *P. geesteranus* shows a decrease in protein, total ash and fibers content from PG1 to PG3 while minerals such as iron and calcium have increased. Levels range from 24.8 to 22.2 g/100 g for crude protein, 8.0 to 7.0 g/100 g for total ash and 38.3 to 33.6 g/100 g for total fibers, while ranges from 9.6 to 13.7 mg/100 g and 9.8 to 26.8 mg/100 g are for iron and calcium respectively. At the end of harvesting, crude lipid levels ranged from 1.2 to 2.0 g/100 g with a maximum of 2.1 in PG2. On the other hand, total carbohydrates, crude polysaccharides and sodium showed an inverse evolution compared to crude lipids. The minima are 58.9 g/100 g for total carbohydrates, 37.8 g/100 g for crude polysaccharides and 36.0 g/100 g for sodium. Regarding the energy value, its calorific intake has observed fluctuations from one harvest to another with 346.6 kcals for PG1; 348.1 kcals for PG2 and 350.7 kcals for PG3.

3.2 Fatty Acid Profile of *P. geesteranus* at Different Harvests

The fatty acid (FA) profile of dried *P. geesteranus* at different periodic harvests is presented in Table 2. The total FA (T) increased from PG1 (1.2) to PG2 (2.1) and then decreased to PG3 (2.0). The unsaturated fatty acids (UFAs) identified are linolenic acid, linoleic acid and oleic acid. These acids represent 56.4% (PG1); 81.2% (PG2) and 75.6% (PG3) of the total FA (T) against 129.4% (PG1); 432.1% (PG2) and 309.1% (PG3) of the total saturated fatty acids (SFAs). Among the UFAs, oleic acid is mainly present in the PG1, PG2 and PG3 harvests with

respective contents of 0.52 g/100 g; 0.87 g/100 g and 1.02 g/100 g. From PG1 to PG3, the UFAs (I) contents evolve from 0.7 to 1.5 g/100 g while PG2 contains 1.7 g/100 g. SFA are composed of palmitic acid; stearic acid and arachidic acid. The total SFAs (S) decreases from PG1 to PG2 (0.5 to 0.4 g/100 g) and then increases to PG3, or 0.5 g/100 g. However, the results indicate that palmitic acid is abundantly present in all harvests.

3.3 Nutritional Profile of the *P. geesteranus* Mushroom at Different Harvests

$SAIN_5$ and LIM_3 values were calculated for the mushroom *P. geesteranus* at different harvests (PG1, PG2 and PG3). The scores obtained were recorded in Table 3. At the end of the different harvests, the LIM_3 scores are relatively low compared to threshold score 7. Among the crops, PG3 had the highest LIM_3 score followed by PG1 (1.0) and PG2 (0.8). For $SAIN_5$, the scores are 15.8 for PG1 and 16.4 for both PG2 and PG3 harvests.

Fig. 1 is the two-dimensional representation of $SAIN_5$ and LIM_3 of the mushrooms *P. geesteranus* from successive harvests. This figure also shows the nutritional and health recommendations. Through this graph, it appeared that the mushrooms from each harvest have $SAIN_5 \geq 5$ and LIM_3 values < 7.5. These characteristic values for the *P. geesteranus* mushroom suggest the most favourable and recommended health profile (Class 1).

Table 1. Nutrient composition of *P. geesteranus* at different harvests

Chemical parameters	Periodic harvesting of the raw mushroom of *P. geesteranus*		
	PG1	PG2	PG3
Crude protein (g/100 g)	24,8 ± 0,0a	23,5 ± 0,0b	22,2 ± 0,0c
Total ash (g/100 g)	8,0 ± 0,0a	7,4 ± 0,0b	7,0 ± 0,0c
Crude Fat (g/100 g)	1,2 ± 0,0c	2,1 ± 0,0a	2,0 ± 0,0b
Total carbohydrates (g/100 g)	59,1 ± 0,1b	58,9 ± 0,1c	60,9 ± 0,1a
Total fibers (g/100 g)	38,3 ± 0,0a	36,0 ± 0,0b	33,6 ± 0,0c
Crude polysaccharide (g/100 g)	43,6± 0,1a	37,8 ± 0,1c	39,8± 0,0b
Energy value (kcal)	346,6± 0,2c	348,1± 0,2b	350,7± 0,3a
Fer (mg/100 g)	9,6 ± 0,0c	12,2 ± 0,1b	13,7 ± 0,1a
Calcium (mg/100 g)	9,8 ± 0,0c	17, 9 ± 0,1b	26,8 ± 0,0a
Sodium (mg/100 g)	20,5 ± 0,1b	15,4 ± 0,0c	75,9 ± 0,1a

The values in the table are derived from the mean of a triple analysis of the sample ± the standard deviation. PG1: P. geesteranus harvested on day 1; PG2: P. geesteranus on day 30 of harvest; PG3: P. geesteranus on day 60 of harvest; (a, b, c): the mean values within the same line with the same superscript letters are not significantly different at the 5% threshold

Table 2. Fatty acid content of the mushroom *P. geesteranus* at different harvests

Fatty acid profile (g/100 g)	Periodic harvesting of the raw mushroom of *P. geesteranus*		
	PG1	PG2	PG3
Palmitic acid *	0,43 ± 0,0a	0,34 ± 0,0b	0,40 ± 0,0c
Stearic acid *	0,08 ± 0,0a	0,06 ± 0,0b	0,07 ± 0,0c
arachidic Acid *	0,02 ± 0,0a	0,00 ± 0,0c	0,02 ± 0,0b
Linolenic acid **	0,02 ± 0,0a	0,01 ± 0,0b	0,02 ± 0,0c
Linoleic acid **	0,14 ± 0,0c	0,82 ± 0,0a	0,47 ± 0,0b
Oleic acid **	0,52 ± 0,0c	0,87 ± 0,0a	1,02 ± 0,0c
Total Fatty Acid (T)	1,2	2,1	2,0
Total saturated fatty acid (S)	0,5	0,4	0,5
Total unsaturated fatty acid (I)	0,7	1,7	1,5
Ratio I/S (%)	129,4	432,1	309,1
Ratio I/T (%)	56,4	81,2	75,6

**Saturated fatty acids; ** Unsaturated fatty acids; The fatty acid composition for each mushroom sample is derived from the mean of a triple analysis and expressed in g per 100 g DM ± standard deviation; PG1: P. geesteranus harvested on day 1; PG2: P. geesteranus harvested on day 30 of harvest; PG3: P. geesteranus on day 60 of harvest; (a, b, c): the mean values within the same line with the same superscript letters are not significantly different at the 5% threshold*

Table 3. $SAIN_5$ and LIM_3 scores of the raw mushroom of *P. geesteranus* at different periodic harvests

Scores	Periodic harvesting of the raw mushroom of *P. geesteranus*		
	PG1	PG2	PG3
LIM_3	1,0	0,8	1,5
$SAIN_5$	15,8	16,4	16,4

PG1: P. geesteranus harvested on day 1; PG2: P. geesteranus on day 30 of harvest; PG3: P. geesteranus on day 60 of harvest

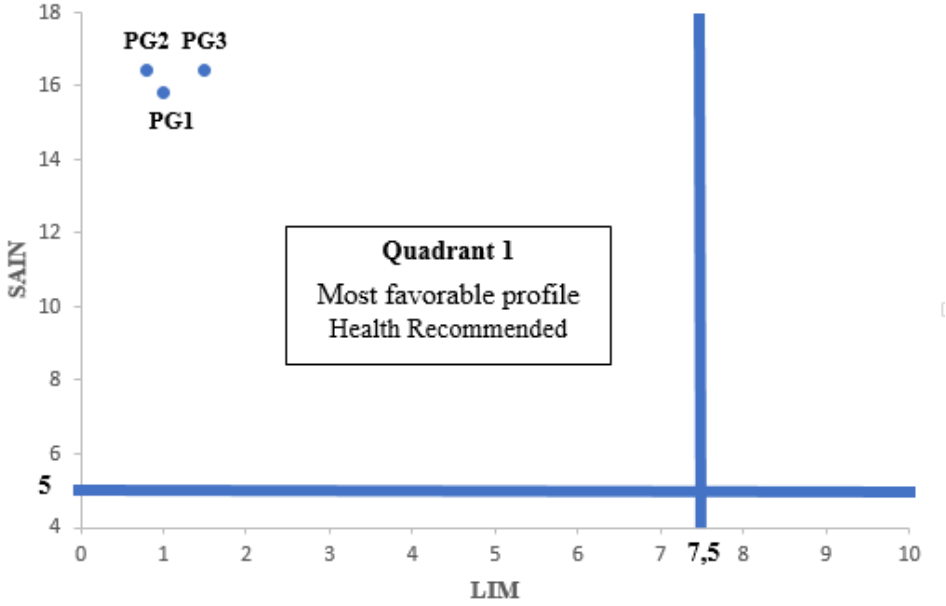

Fig. 1. Nutritional profile of the raw *P. geesteranus* mushroom at different periodic harvests

PG1: P. geesteranus harvested on day 1; PG2: P. geesteranus on day 30 of harvest; PG3: P. geesteranus on day 60 of harvest

4. DISCUSSION

At different harvests, significant changes were observed in all the chemical parameters studied on the mushroom *P. geesteranus*. These differences were either related to intrinsic factors of the substrate or associated with the ecological conditions (temperature of the growing medium, air composition, relative humidity and luminosity of the room) in the fruiting room. Bellettini et al. [11] argued that each of the parameters could interact with each other or act separately. Consequently, the nutrient acquisition mode of the substrate could be influenced by these parameters and subsequently modify the nutritive value of the mushroom. This explains, for example, the decrease in protein content in the fruit body of *P. geesteranus* when observing different crops. This decrease in protein would also be associated with the decrease in the initial nitrogen content of the substrate. These results are in line with different studies on different species of the genus Pleurotus with protein contents ranging from 11 to 42 g per 100 g of dried body [22,23].

Analyses also indicated low lipid levels in the fruit body of *P. geesteranus* from one harvest to another. Being hypolipidic, this edible mushroom is endowed with polyunsaturated fatty acids (linolenic acid and linoleic acid), monounsaturated acid (oleic acid) and saturated fatty acids (palmitic acid, stearic acid and arachidic acid). The presence of these essential fatty acids confers important physiological effects for the proper functioning of the organism apart from their energetic role [24]. SFAs, in general, are recognized for their role in raising total cholesterol [25], but the effect is variable depending on the SFA. Indeed, the most

hypercholesterolemic are, in decreasing order, myristic, lauric, palmitic and stearic acids [25]. Based on this observation, the acids detected (palmitic acid (C16:0) and stearic acid (C18:0)) in this mushroom contribute less to hypercholesterolemia. Stearic acid (C18:0) could also play a structural role as a constituent of membrane phospholipids. In addition to being antiatherogenic, these physiological effects would also be associated with the activities of oleic acid (monounsaturated acid). Concerning unsaturated fatty acids, Guesnet et al. [24] indicated that linolenic acid and linoleic acid were metabolic precursors of omega-3 and omega-6 respectively. These polyunsaturated acids also have an antiatherogenic effect. Sufficient consumption of the *P. geesteranus* mushroom could be beneficial in the prevention of cardiovascular diseases (myocardial infarction, stroke, etc.), as they lower triglyceride and bad cholesterol (LDL) levels in favor of good (HDL). In fact, this is what limits the formation of atheroma plaque in the vessels [26].

Several studies have attributed hypoglycemic activities to the genus *Pleurotus*, hence their antidiabetic effect on animals [27,28,29,30,31]. This antidiabetic potential is thought to be related to polysaccharide extracts. For this reason, mushrooms of Pleurotus sp. species are considered a functional food, according to Chang and Miles [32] and Adebayo and Oloke [33].

Fig. 1 shows the two-dimensional positioning of harvested mushrooms PG1, PG2 and PG3 according to their respective nutritional profiles. The main information that emerges is that the *P. geesteranus* mushroom remains of excellent nutritional quality regardless of the harvest. This result is justified by the $SAIN_5 \geq 5$ and LIM_3 scores < 7.5 from chemical analyses of the mushrooms after each harvest [21]. In view of the results obtained, the link between the harvest times of the *P. geesteranus* mushroom and the nutrient variations observed during the physico-chemical analyses would not have modified the nutritional profile of the *P. geesteranus* mushroom in any way. The categorization of all the mushrooms samples in frame 1 of the recommended foods is the perfect justification for this (Fig. 1). These conclusions are therefore of great interest for people suffering from metabolic diseases such as diabetes mellitus that the *P. geesteranus* mushroom meets all the conditions for access to health claims according to French Food Standard Agency (AFSSA) [8]. Indeed, for this organization, only foods listed in quadrant 1, i.e. at $SAIN_5 \geq 5$ and $LIM_3 < 7.5$ have access to nutrition and health claims. In other words, this mushroom can be consumed without any restriction, let alone regardless of the harvest. In general, the substitution of foods of poor profile with foods of good profile improves the nutritional quality of the subject's diet [34]. And, the mushrooms *P. geesteranus*, used as an ingredient in various meals, is becoming an increasingly important part of people's daily diet. It can therefore be recommended for consumption without moderation.

5. CONCLUSION

The study clearly indicated that this cultivated mushrooms is likely to promote $SAIN_5$ and reduce LIM_3 (SAIN ≥ 5 and LIM < 7.5) regardless of the crop. Its nutritional profile also suggests a beneficial effect on general health. The use of this simplified nutritional information system thus makes a significant contribution in the face of data deficits on the nutritional quality of certain NTFPs, in this case edible mushrooms from soil-less cultivations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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