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# Influence of organic agricultural practices compared to conventional agricultural practices on the nutritional and functional characteristics of strawberry *Fragaria* × ananassa cultivar inspire

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## ABSTRACT

This study compares the organic cultivation method and the conventional method to see which system produces more nutritious, more functional and healthier strawberries. It reveals that fruits from organic farming contain more dry matter (9.37%) than conventional ones (8.77%), soluble sugars 6.69 °Brix against 5.74 °Brix, proteins (0.85% against 0.74%), ash (0.58% against 0.48%) and energy (36.28 kcal/100 g against 34.59 kcal/100 g), a sign of a higher nutritional density. They also accumulate more zinc (5.73 mg/kg versus 3.53 mg/kg), iron (0.47 mg/kg versus 0.37 mg/kg) and copper (2.85 mg/kg versus 2.21 mg/kg), while conventional strawberries display higher levels of potassium, calcium and phosphorus (respectively 1807.33, 182.33, and 256 mg/kg). In addition, organic strawberries contain more polyphenols (242.6 mg/g versus 176.833 mg/g) and anthocyanins, accompanied by a more pronounced antioxidant activity. The distribution of sugars is also more favorable in organic mode, with a preference for fructose (2.833 g/100 g) and sucrose (0.847 g/100 g) which enhances the taste. In terms of health, pesticide residues appear only in conventional strawberries, while organic products appear to be free of any trace. This observation validates one of the main advantages of organic farming in terms of food safety.

**Keywords:** *Fragaria×ananassa*, biological system, conventional system, nutritional composition.

## INTRODUCTION

The global yield of various fruits exceeds millions of tons, depending on geographical regions, consumption habits and cultural practices, which inevitably leads to significant amounts of by-products and waste. The genus *Fragaria* (*Rosaceae*), commonly known as strawberry, constitutes one of the most important food crops in the world, its production levels being double those of all other berry varieties combined (Liston et al., 2014). In Morocco, strawberry cultivation is mainly concentrated in the Gharb and Loukkos regions (north-west).

The number of species in the genus remains a subject of debate, ranging from 22 to 16 (Fierascu et al., 2020). In general, all *Fragaria* species share common characteristics: they are slow-growing perennials, generally evergreen and trifoliolate, pollinated by insects, and bearing white actinomorphic flowers. The main difference between the species lies in the accessory aggregate fruits scattered by the animals, in terms of color, shape and position of the achenes (simple fruits with 1 seed) and the calyxes when ripe. The different composition and other characteristics of these fruits also determine the potential commercial value of the species. Many cultivars are perennials whose photoperiod needs vary, which leads to variable harvest periods (June fruits, remontant fruits, neutral days) (Petran, 2016). Among the 247 varieties identified, a limited number have significant commercial relevance: *Fragaria* × *ananassa* (an octoploid hybrid characterized by 56 chromosomes, commonly known as garden strawberry, native to North America and cultivated worldwide) (Liston et al., 2014).

The intensive use of these fruits, mainly attributed to their palatability, can also have important benefits for human health. In addition to various attributes, non-visual characteristics such as flavor, nutritional content and fragrance make these fruits one of the main choices of consumers (Awad and De Jager, 2003). Epidemiological investigations have indicated that a large consumption of fruits and vegetables can confer protection against chronic diseases (Joshipura et al., 2001; Riboli and Norat, 2003).

The class of phenolic constituents of strawberries that has always been the object of the greatest attention is that of anthocyanins, which give the fruit its characteristic bright red hue. Therefore, the concentration and profile of anthocyanins are crucial for the sensory characteristics of fruits and their derived products, while presenting potential health benefits. Another notable category of phenolic compounds in strawberries is that of hydrolysable tannins, which are found only in a limited number of other berries and nuts (Clifford and Scalbert, 2000). In addition, strawberries are characterized by high levels of proanthocyanidins (Gu et al., 2003; Buendia et al., 2010). The phenolic compounds present in comparatively smaller quantities in strawberries include flavonols (Määttä-Riihinen et al., 2004; Aaby et al., 2005; Buendia et al., 2010).

The chemical composition of *Fragaria* × *ananassa* varies considerably depending on the genetic makeup of the organism (Anttonen et al., 2006; Capocasa et al., 2008), while being influenced by extrinsic factors such as agricultural methodologies, environmental conditions and the stage of maturity at which the fruit is harvested (Pineli et al., 2011; Tulipani et al., 2011).

Strawberries face many phytosanitary challenges. Environmental conditions associated with insufficient storage methods contribute to the proliferation of various pathogens that adversely affect the quality of strawberries. These fruits can be susceptible to viruses (Li and Yang, 2011), bacteria (Bull et al., 2011), mites (Lagziri and El Amrani, 2009), nematodes (Lamindia, 2002), pests (Nicolov, 2006), weeds (Lansari, 1985), and fungi (Paulus, 2002), The incidence of fungal diseases in strawberries has important economic repercussions in the regions cultivated from all over the world.

Strawberries are appreciated all over the world; however, their vulnerability to pests and diseases, aggravated by their extensive cultivation, requires the application of many products, including synthetic fertilizers and pesticides. At the same time, there is a growing demand for nutritious food grown according to sustainable practices, which underlines the importance of organic farming.

In Morocco, strawberries play a central role in the agricultural sector, responding to both domestic consumption and export markets. To improve varietal diversity, Moroccan farmers have launched a program aimed at introducing new strawberry cultivars that stand out for their organoleptic characteristics, in particular their resistance to diseases and their shelf life, such as *Fragaria* × *ananassa*, which stands out for its superior agronomic characteristics.

Nevertheless, there is little research in Morocco that has evaluated the consequences of the exclusive use of animal manure, without pesticides, on the nutritional characteristics of the main strawberry cultivars. It is therefore imperative to elucidate the influence of this local biological system on the chemical composition of the fruits, unlike the conventional agricultural methodologies currently used.

Thus, the present study makes it possible to better understand the influence of the cultivation system (both conventional and organic, using animal manure without pesticides) on the nutritional and physicochemical quality of *Fragaria* × *ananassa* cv. Inspired, grown in Morocco.

## MATERIEL AND METHODS

### Preparation of plant material and samples

The experiment at the level of Ouled Aguil (Moulay Bousselham, Kenitra province) (34° 51’ 41” N 6° 9’ 56” W) compared two strawberry cultivation systems (*Fragaria* × *ananassa* cv. Inspire) planted in October 2024. The two cultivation systems were: a conventional greenhouse test and an above-ground biological test. In the conventional system, on sandy soil (pH 6.52), a greenhouse is equipped with plastic mulching, drip irrigation, fertilization for organic and mineral soil analysis, and phytosanitary tending to the recommended thresholds. Organic without greenhouse or pesticides, relying only on sheep manure vermis as fertilizer, with plants grown in pots. The two tests having integrated similar pedoclimatic conditions, were judged at equivalent levels of maturity, in similar storage and transport conditions to ensure a reliable differentiation between agronomic and qualitative performances.

## Proximate analysis

To determine moisture content, the sample heated at 105 °C and maintained that temperature until its mass stabilized, indicating complete moisture evaporation (Aouji et al., 2023).

As described by AOAC, (2010), the measurement of dry matter is conducted by drying the sample at 70 °C. This procedure ceases when the difference in mass between two weighings done 2 hours apart is at least 3 mg.

The pH measurement was done following the procedure of Brunetti et al. (2019). Also, the determination of the acids was identified by titrating with a 20% sodium hydroxide (NaOH) solution using phenolphthalein as an indicator according to Benahmed-Djilali et al. (2017).

Using the refractometer, a drop of juice is taken and deposited on the refractometer, read the value on the refractometer it directly indicates the Brix value (ISO 2173, 2003).

The total ash was evaluated following ISO 936, (1998) standards through a gravimetric approach which consists of burning samples at 550 °C. The results are expressed as percentage of total ash out of 100 grams of dry matter.

The overall amount of protein was evaluated according to AOAC method 928.08 (AOAC, 2000), and results were expressed as grams per hundred grams of total dry weight. The protein content estimation used a nitrogen determination in combination with a Jones factor of 6.25.

The average lipid content was evaluated with the Soxhlet method and is shown as grams per one hundred grams of wet weight (AOAC, 2000).

According to Equation 1, the amount of carbohydrates was calculated by deducting the amounts of fats, proteins and ash from the value of the dry matter (Nannu et al., 2014).

$$Carbs\ (\text{g/100g}) = DM - (P + A + F) \quad (1)$$

where: $DM$ represents the total dry matter (%), $P$ – the protein content (%), $A$ – the ash content (%) and $F$ – the total fat (lipid content) (%).

Minerals were analyzed from a 1 g ash sample which was produced after heating for 16 hours at 480 °C. The ash was treated with 25% concentrated nitric acid and filtered. This solution was then analyzed for the minerals of interest. ICP-AES with an RF power of 1500 W, plasma gas (Ar) flow of 8 L/min, auxiliary Ar gas of 0.2 L/min, axial view, and read/copy times of 45 minutes/15 minutes was used to measure the trace elements (Aouji et al., 2023).

The samples are treated with acetonitrile to extract pesticide residues. After the incorporation of a saline buffer composed of citrate and sodium, as well as magnesium, the sample is subjected to vortex homogenization, followed by centrifugation. After that, is then purified by d-SPE and consists of a mixture of $MgSO_4$, PSA (primary secondary amine). This treatment is used to eliminate the chemicals that disrupt the analysis, as well as the water that remains. A small amount of formic acid is incorporated, in order to adjust the pH. The pesticide residues identified in the purified sample will be measured with the liquid chromatography technique coupled to mass spectrometry (LC-MS) (NF EN 15662, 2018).

## Quantitative analysis and antioxidant activity

The fruits must first be harvested at the same stage of maturity, discarding those that are damaged or altered. The fruits are washed with distilled water to rid them of all impurities. Then peeled with a knife, then weighed to plus or minus 50 g. Thereafter, mixing is carried out with 100 mL of distilled water until a homogeneous puree is obtained. The resulting juice is then filtered through sterile gauze to remove the solid particles. Then the placed in glass vials and sterilized, hermetically sealed.

The total phenol content was determined by the Folin–Ciocalteu method reported by Aouji et al. (2023). On the other hand, the total flavonoid content was determined using the $AlCl_3$ method as per Zirari et al. (2024). On the other hand, the technique Giusti et al. (2001) uses differential pH allows a rapid and accurate measurement of total anthocyanins.

For the evaluation of antioxidant activity, different extract concentrations in ethanol were combined with 1950 µL of freshly prepared 0.024 g/L DPPH solution in a set of tubes to make a reaction mixture. The tubes were mixed well and then kept for a time period of 30 min at room temperature. Afterwards, sample absorbances were taken against blank at the wavelength of 515 nm (Sasikmar et al, 2020). Absorbance reading was performed along with a negative control where instead of the extract, 50 µL methanol was used resulting into no change alongside equal parts DPPH solution. Percent inhibition was determined according to Equation 2.

$$\%\,Activity = \frac{Abs\ Cn - Abs\ Ech}{Abs\ Cn} \times 100 \quad (2)$$

where: $Abs_{Ech}$ – absorbance of the sample
$Abs_{Cn}$ – absorbance of negative control.

The quantification of glucose, sucrose and fructose was carried out according to the methodology established by Yu et al. (2016) using ion chromatography. The separations were carried out on a Dionex CarboPac PA10 anion exchange column. An 18 mM sodium hydroxide (NaOH) solution served as the mobile phase, administered in isocratic mode with a flow rate of 1.0 mL/min. The temperature of the column was constantly maintained at 32 °C. and the injection volume was adjusted to 20 µL. The detection was carried out thanks to an amperometric pulse detector (pulsed amperometric detection, PAD). Under these specified conditions, the separation and the quantitative evaluation of the three saccharides (glucose, sucrose, fructose) were carried out in less than 18 minutes.

Using statistical software (SPSS, ver. 27), the data was subjected to a one-way ANOVA, followed by Tukey's test ($\alpha = 5$) for multiple comparisons and significance level determination. Three repetitions' average value is shown. $p < 0.05$ was regarded as statistically significant.

## RESULTS AND DISCUSSION

### Proximate analysis

Table 1 shows the approximate composition, statistically, there is a significant difference regarding the water content, which is higher in the conventional treatment (91.45 ± 0.20%) than in the biological treatment (90.8 ± 0.23%) ($p < 0.05$). On the other hand, the dry matter follows the opposite trend, being higher in the biological treatment (9.37 ± 0.11%) than in the conventional treatment (8.77 ± 0.21%). These results suggest that fruits from organic farming contain a higher concentration of solids, which improves their organoleptic properties. These observations are consistent with the work of Caris-Veyrat et al. (2004), which reported a significantly higher dry matter content in the biological system. This difference is usually attributed to slower growth and a more progressive availability of water and nutrients, characteristics of the organic mode.

The biological treatment has a higher titratable acidity (0.87 ± 0.06%) compared to the conventional treatment (0.75 ± 0.04%), which indicates that the difference is not statistically significant ($p > 0.05$). The pH level is significantly lower in organic fruits (3.34 ± 0.05) compared to conventional fruits (3.53 ± 0.09). This also proves the increased acidity. This corroborates the results of Caris-Veyrat et al. (2004) concerning organic fruits with a more pronounced acidity, which helps to maintain microbial stability and improve flavor.

The soluble sugar content, expressed in °Brix, is significantly higher in fruits from organic farming (6.69 ± 0.31 °Brix) compared to those from conventional processing (5.74 ± 0.14 °Brix). This translates into a higher, sweeter sensory quality and this is a very important criterion for consumers. This result is in agreement with Reganold et al. (2010), who have highlighted that organic agricultural practices favor the economic allocation of soluble compounds, such as sugars, in response to moderate levels of environmental stress.

The biological treatment gave fruits that had a statistically significantly higher protein value of 0.85 ± 0.02% compared to fruits treated conventionally 0.74 ± 0.04%. Although the plant serves as a moderate source of protein, it is insufficient when juxtaposed with the recommended nutritional intake of protein, set at 56 g for individuals weighing 70 kg and 46 g for adults weighing 50 kg (Zirari et al., 2023). Proteins of plant origin are generally considered to be of inferior quality, but when integrated with other protein sources such as proteins of animal origin, they can result in a sufficient nutritional profile (Zirari et al., 2024).

In the same way, the lipid content is also slightly higher in the biological treatment 0.38 ± 0.05% against 0.34 ± 0.04% in the conventional, even if this difference is not significant. A diet

**Table 1.** Proximate composition of conventional and biological treatment

| Parameters | Conventional treatment | Biological treatment |
|---|---|---|
| Water content (%) | 91.45 ± 0.20 $^{a}$ | 90.8 ± 0.23 $^{b}$ |
| Dry matter (%) | 8.77 ± 0.21 $^{a}$ | 9.37 ± 0.11 $^{b}$ |
| Acidity (%) | 0.75 ± 0.04 $^{a}$ | 0.87 ± 0.06 $^{a}$ |
| pH | 3.53 ± 0.09 $^{a}$ | 3.34 ± 0.05 $^{a}$ |
| Soluble sugar (°Brix) | 5.74 ± 0.14 $^{a}$ | 6.69 ± 0.31 $^{b}$ |
| Protein (%) | 0.74 ± 0.04 $^{a}$ | 0.85 ± 0.02 $^{b}$ |
| Crude fat (%) | 0.34 ± 0.04 $^{a}$ | 0.38 ± 0.05 $^{a}$ |
| Carbohydrate (%) | 7.14 ± 0.22 $^{a}$ | 7.35 ± 0.14 $^{a}$ |
| Ash content (%) | 0.55 ± 0.02 $^{a}$ | 0.78 ± 0.03 $^{b}$ |
| Energy (Kcal/100 g) | 34.59 ± 0.90 $^{a}$ | 36.28 ± 0.48 $^{a}$ |

**Note:** The significant difference ($p < 0.05$) between the different extracts is illustrated by the letters a and b.

providing 1 to 2% of its caloric intake in the form of lipids is considered adequate for human consumption, since excessive fat consumption has been linked to the development of obesity and cardiovascular diseases (Zirari et al., 2024). In addition, lipids play a crucial role in the diet by serving as a valuable energy source, facilitating the transport of fat-soluble vitamins, contributing to cellular functions. In addition, Woese et al. (1997) noted the same models, arguing that the moderate stress that is often inflicted on organic farming can be beneficial by increasing the accumulation of proteins and other primary metabolites, although this is often rather mild.

In the biological treatment, the total carbohydrate is indeed slightly higher (7.35 ± 0.14%) than in the conventional treatment (7.14 ± 0.22%). This confirms the trend observed for soluble sugars. The difference, although slight in this case, remains relevant nutritionally. Carbohydrates play a crucial role in providing the energy necessary for bodily functions, serving as essential nutrients for a balanced diet (Zirari et al., 2023). They are responsible for feeding various cells of the body, including those of the brain, muscles and blood (Ejelonu et al., 2011).

It appears that at the level of the biological treatment, the ash concentration is considerably higher (0.78 ± 0.03%) than at the conventional treatment (0.55 ± 0.02%). This suggests a greater microbial activity and a better soil structure in biological system. Rembiałkowska (2007) had conducted a study and confirmed that products from organic farming, especially grown on soils well amended in compost, contain much more certain minerals in comparison with their conventional counterparts (Fe, Mg, Zn).

Overall, the results obtained show that the fruits from organic farming have a nutritional and technological quality superior to those from conventional agriculture (36.28 ± 0.48 kcal/100 g against 34.59 ± 0.90 kcal/100 g). These findings are in line with a relatively abundant scientific literature suggesting that the organic production method can improve the nutritional composition of fruits (Brandt and Mølgaard, 2001; Lairon, 2010), even if the differences are not always significantly different. Soil fertility, moisture content and growth temperature are the main environmental factors that influence the nutritional composition of plants grown in different regions.

The study of the mineral composition shows a specific variation, strawberries from conventional agriculture have higher levels of calcium, potassium, magnesium and phosphorus. On the other hand, organic fruits showed amounts of zinc (5.73 ± 0.15 mg/kg versus 3.53 ± 0.10 mg/kg), copper (2.85 ± 0.04 mg/kg versus 2.21 ± 0.03 mg/kg), iron (0.47 ± 0.02 mg/kg versus 0.37 ± 0.02 mg/kg) and chlorine (7.60 ± 0.04 mg/kg versus 7.51 ± 0.03 mg/kg) significantly higher. These results suggest that differential fertilization and the bioavailability of nutrients in organic soils impact absorption processes. Mäder et al. (2007) confirm these results, stressing that the type of fertilizer used in organic farming can influence the trace element content of plants (Table 2).

## Quantitative phytochemical analysis

The concentration of phenolic compounds in natural products constitutes a crucial metric for the quantitative assessment of extracts and their associated biological activity, owing to the

**Table 2.** Minerals content of conventional and biological treatment

| Minerals | Concentration (mg/kg) | |
|---|---|---|
| | Conventional treatment | Biological treatment |
| Calcium | 182.33 ± 2.52 [a] | 166.67 ± 2.52 [b] |
| Sodium | 1.94 ± 0.04 [a] | 2.11 ± 0.04 [b] |
| Potassium | 1807.33 ± 7.51 [a] | 1424.67 ± 4.51 [b] |
| Magnesium | 161.33 ± 2.52 [a] | 154.67 ± 4.51 [a] |
| Iron | 0.37 ± 0.02 [a] | 0.47 ± 0.02 [b] |
| Manganese | 0.48 ± 0.03 [a] | 0.48 ± 0.02 [a] |
| Zinc | 3.53 ± 0.10 [a] | 5.73 ± 0.15 [b] |
| Copper | 2.21 ± 0.03 [a] | 2.85 ± 0.04 [b] |
| Phosphorus | 256 ± 2.65 [a] | 220 ± 3.00 [b] |
| Chlorine | 7.51 0.03 [a] | 7.60 0.04 [b] |

**Note:** The significant difference ($p < 0.05$) between the different extracts is illustrated by the letters a and b.

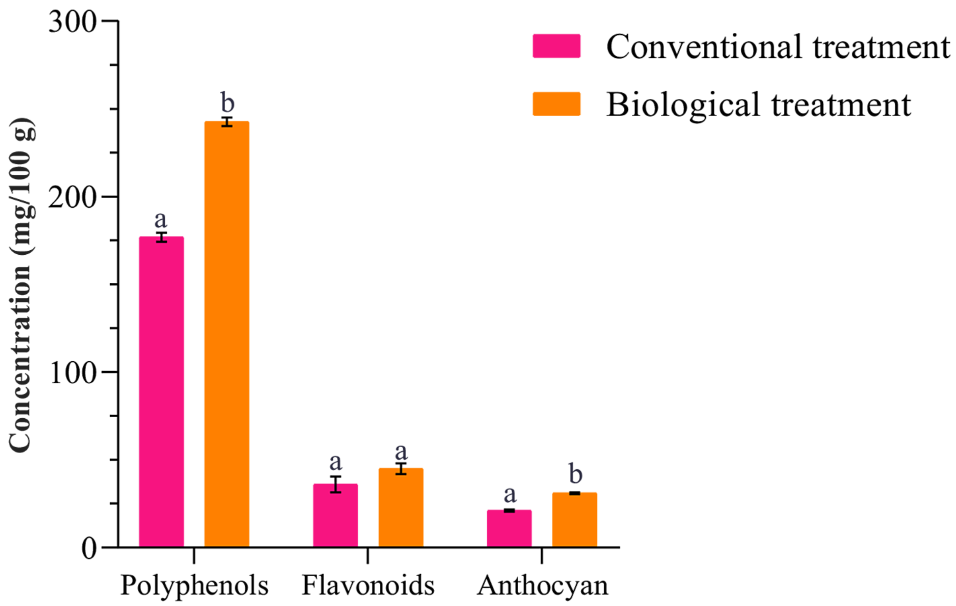


**Figure 1.** Composition of phenolic compounds of conventional and biological treatment. The significant difference ($p < 0.05$) between the different extracts is illustrated by the letters a and b

significant roles these compounds play in fundamental physiological processes (Naz et al., 2020) (Figure 1).

The study of the phenolic composition shows notable differences according to the type of culture. The fruits obtained from the biological treatment contain significantly more total polyphenols (242.60 ± 2.506 mg/g) compared to the samples obtained from the conventional system (176.833 ± 2.466 mg/g). This indicates an increased synthesis of secondary metabolites in plants grown by biological bias. This increase, often observed in organic crops, is generally interpreted as a physiological response to certain types of stress, more frequently observed in systems without chemical inputs, such as moderate fungal attacks or water variations (Brandt et al., 2011).

The pigments responsible for the red coloration of the strawberry as well as its antioxidant activity, the anthocyanins, are also better dosed in the biological treatment. This reinforces the idea that organic cultivation further stimulates the expression of secondary metabolic pathways, and more particularly those related to the natural defenses of the plant. A correlation between the agricultural methodology and the chemical composition of strawberries has been identified by Crecente-Campo et al. (2012), the researchers noted high levels of detected anthocyanins (corresponding to a more intense red hue and better nutritional quality) in strawberries grown according to organic practices. On the other hand, at the level of total flavonoids, no significant difference is observed. This could testify to the fact that these compounds are less sensitive to changes related to the cultivation method or that their production is strongly controlled by varietal genetics.

## Antioxidant activity

A significant difference between the two treatments was observed at the evaluation of the antioxidant activity, measured by the value of $IC_{50}$. The strawberries obtained by the biological process had a lower $IC_{50}$ (2087 ± 8.888 mg/mL) compared to those of the conventional process (2673 ± 4.359 mg/mL), thus showing a superior antioxidant activity of the organic fruits ($p < 0.05$). This result is explained by the higher presence of polyphenols and anthocyanins in the biological samples, the latter being free radicals that they neutralize. Olsson et al. (2006) who observed a greater antioxidant activity in organic fruits, attributed to an increased diversity of phenolic compounds due to environmental stress (non-use of pesticides, living soil, etc.) (Figure 2).

## Sugar composition

The study of the sugar composition shows notable differences between strawberries from conventional treatment and those from biological treatment. The fructose and sucrose concentrations are substantially higher in the fruits grown according to the biological system, with respectively approximately 2.833 ± 0.031 g/100 g FW for fructose and 0.847 ± 0.021 g/100 g FW for sucrose against 2.637 ± 0.015 g/100 g and 0.723 ± 0.025 g/100 g in conventional fruits. These results show that organic strawberries tend to store more fructose, which is the most common sugar, and simple sugars, which makes them sweeter. On the other hand, the glucose content is slightly higher in conventional samples, although this difference remains modest (2.547 ± 0.045 g/100 g FW versus 2.347 ± 0.021 g/100 g FW). The increase in sucrose content could also be due to a more active enzymatic activity, stimulated by the biological quality of the soil (Figure 3).

## Pesticide analysis

The results obtained show that the batch of conventional strawberries examined complies well with the safety thresholds set by the European Union. The five chemicals identified, despite all being present in measurable quantities, are far below the MRL, which indicates that an ordinary consumer almost does not pay attention to them. These findings are confirmed by the EFSA, (2023) exposure model, which leaves a wide margin of safety, especially for sensitive groups. That said, the cumulative presence of

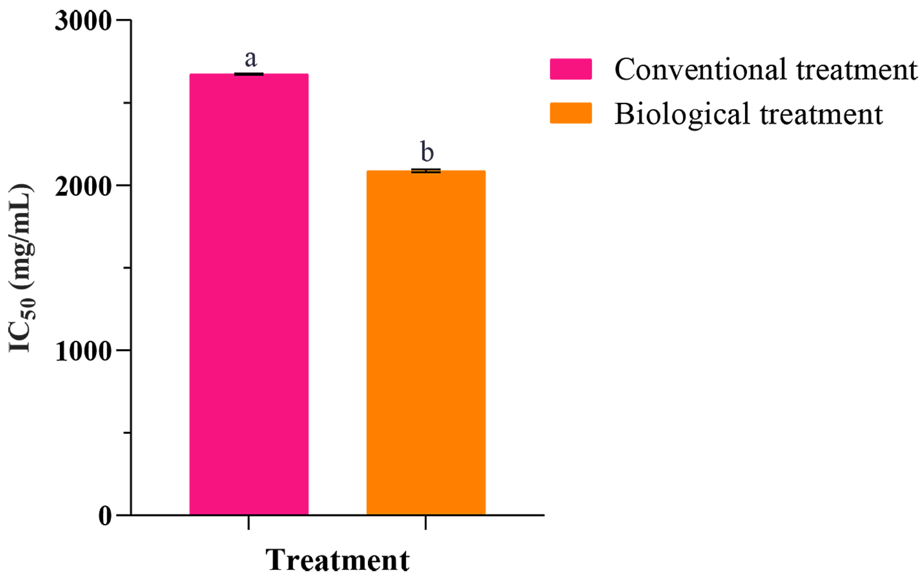


**Figure 2.** Evaluation of the antioxidant activity of conventional and biological treatment. The significant difference ($p < 0.05$) between the different extracts is illustrated by the letters a and b

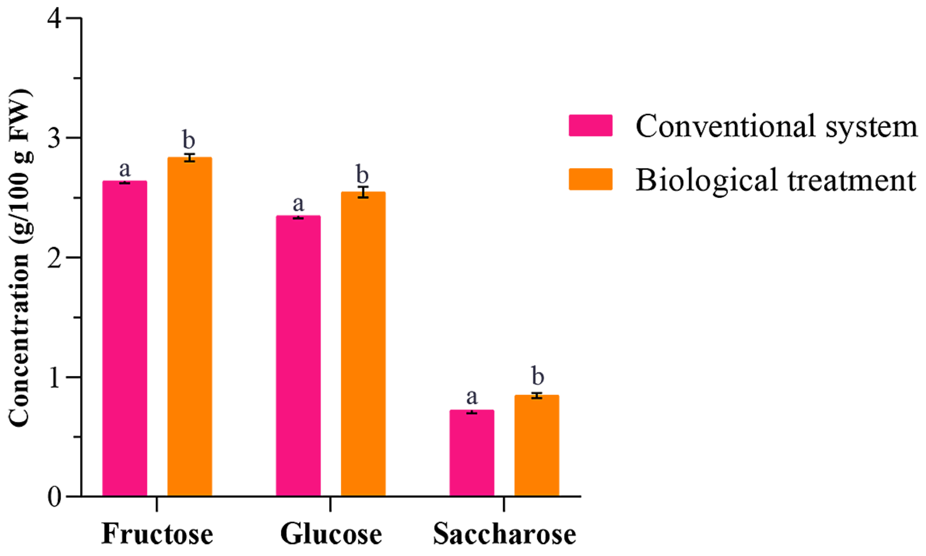


**Figure 3.** Sugar composition of conventional and biological treatment. The significant difference ($p < 0.05$) between the different extracts is illustrated by the letters a and b

residues, even in small doses, should still encourage us to keep an attentive eye. Indeed, the long-term effects of chronic contact with cocktails of substances and their possible interactions are still poorly known and constitute a new challenge for food toxicology (Table 3).

Conversely, organic strawberries do not contain any trace of chemicals, proof that it is forbidden to use synthetic pesticides and that alternative methods work. This chemical cleanliness is a real plus for consumers who prefer food without added substances (Table 4).

These results add to an already well-developed corpus. According to EFSA, (2023), more than 60% of strawberries tested in the Union have pesticide residues, often 2 to 3 substances per fruit. On the other hand, several studies point out that certified organic fruits display a much more reassuring profile. Baker et al. (2002) had thus observed that less than 1% of organic strawberries contained measurable traces, and that the levels found were on average 90% lower than those of conventional fruits.

The observed exposure to pesticides remains well below the levels usually considered

**Table 3.** Compliance of pesticide residues with the maximum permissible limits

| Criterion | Conventional treatment | Biological treatment |
|---|---|---|
| Number of pesticides detected | 5 | 0 |
| Residue levels | 0.036–0.264 mg/kg | < 0.010 mg/kg |
| Estimated health risk | Low to negligible | None |
| Regulatory compliance | Compliant | Compliant |
| Environmental impact | Potentially significant | Low to very low |

**Table 4.** Concentration of pesticides detected in conventional strawberries and compliance with the maximum residue limits (EU-MRL)

| Active substance | Qt (mg/kg) | EU-MRL (mg/kg) | Exceeding MRL? |
|---|---|---|---|
| Azoxystrobin | 0.036 | 10.00 | No |
| Bupirimate | 0.264 | 1.50 | No |
| Ethyrimol | 0.047 | N/L | Uncertain |
| Spirotetramate | 0.085 | 0.30 | No |
| Tetraconazole | 0.040 | 0.20 | No |

**Note:** N/L = Not listed.

dangerous (ADI and ARfD). However, INSERM (2021) recalls that certain substances could act as endocrine regulators or even cause cancers: these risks, even minimal and repeated, therefore force the authorities to adopt precaution, especially for children and pregnant women.

## CONCLUSIONS

This study clearly reveals that the cultivation method influences the quality of strawberries. Organic fruits show higher levels of nutrients, essential minerals and antioxidants. As a result, their fruits exhibit superior antioxidant activity, which means that they neutralize free radicals more effectively. In addition, pesticide residue analyzes show no trace in organic strawberries, while conventional ones carry several, certainly under the legal thresholds. This difference underlines the enhanced health safety of organic products, an essential criterion for the consumer and for a sustainable diet. In total, the organic mode offers a trio of advantages: nutritional value, functional quality and safety, which legitimizes its development in current agri-food policies. However, these results encourage further research to evaluate the bioavailability of these compounds and the long-term effect of their ingestion on human health.

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