EEET ECOLOGICAL ENGINEERING
& ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology, 2026, 27(7), 306–323
https://doi.org/10.12912/27197050/224337
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Received: 2026.05.23
Accepted: 2026.06.15
Published: 2026.07.01

Organic vs conventional cultivation modulates soil properties, yield and bioactive compounds in two strawberry cultivars (Llosana and Fortuna): Insights into fruit quality, health potential and sustainable production

Nazha Lamdardar[1], Marouane Aouji[1*], Radia Braouzi[2], Rachid Bengueddour[1]

[1] Laboratory of Natural Resources and Sustainable Development, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco
[2] Production and Export of Strawberries, Institute of Technicians Specialized in Horticulture; Meknes; Morocco
* Corresponding author's e-mail: aouji.marouane@uit.ac.ma

ABSTRACT

This study evaluated the effect of two cultivation systems (organic and conventional) on the soil properties, agronomic performance, and biochemical quality of strawberries of the Llosana and Fortuna varieties. The soil analysis revealed an improvement in the organic status in a biological system, characterized by a higher organic matter content (1.85%) and a lower C/N ratio (11.0), indicating increased microbial activity. On the other hand, the conventional system showed higher concentrations of trace elements, in particular iron and manganese. From an agronomic point of view, the conventional system has significantly improved growth and yield, with values reaching 883.33 g for Fortuna and 806.33 g for Llosana, against 538.00 g and 480.33 g, respectively, in the organic system. However, the latter favored a better nutritional quality, with an increase in dry matter, soluble sugars, and proteins. Biochemical analyzes have shown that the biological system stimulates the accumulation of phenolic compounds and strengthens antioxidant activity, with a significant increase in total antioxidant capacity and a decrease in IC_{50} values. Moreover, the volatile profiles revealed a dominance of esters in the conventional system, conferring fruity aromas, while the biological system favors furanones, responsible for more complex and sweet aromas. Finally, the antibacterial activity was more marked in the extracts from the biological system, suggesting an increased accumulation of bioactive compounds. These results highlight a compromise between yield and quality and underline the importance of choosing the cultivation system according to the production objectives.

Keywords: *Fragaria* × *ananassa*, organic cultivation, conventional cultivation, soil physicochemical properties, agronomic performance, fruit quality, GC–MS, sustainable agriculture.

INTRODUCTION

The strawberry (*Fragaria* × *ananassa* Duch.) is one of the most cultivated fruit species in the world, due to its economic potential, its richness in bioactive compounds (vitamin C, anthocyanins, and polyphenols) and its acceptability by consumers. The quality and productivity of this crop depend very largely on the agronomic management implemented, in particular the cultivation system, which conditions the availability of nutrients, the biological dynamics of the soil, and the pressure of the bioaggressors (Giampieri et al., 2017; Reganold et al., 2010). In a context of transition to more sustainable agricultural systems, questioning the differences between the conventional and the organic system for productivity, fruit quality, and the environment has become a major issue.

The conventional system, characterized by the use of synthetic mineral fertilizers, and plant protection products, usually makes it possible to achieve high yield levels and a high commercial quality of the fruits. It is necessary to pay particular attention to the application of fertilizers, to the rapid availability of essential nutrients such as nitrogen, phosphorus, and potassium, favoring the development of vegetative growth, the formation of reproductive organs, and the filling of fruits (Yasir et al., 2025). The choice of fungicides and crop protection products also makes it possible to limit the damage caused by fungal diseases, for example gray rot caused by *Botrytis cinerea*, one of the main causes of economic losses in strawberry production (Petrasch et al., 2019). However, this type of intensive practices can, however, lead to various negative impacts on the soil, among which the decrease in microbial biodiversity, the disruption of biogeochemical cycles, and environmental pollution (Steiner et al., 2024).

Conversely, the biological system is based on the implementation of ecological, agronomic practices such as the addition of organic amendments, the diversification of rotations, and the reduction of chemical inputs. Such systems make it possible to optimize the physico-chemical and biological properties of the soil, such as the organic carbon content, the cation exchange capacity, and the enzymatic activity (Lori et al., 2024; Yang et al., 2024), in favor of an increased resilience of agroecosystems. The literature indeed demonstrates that soils cultivated in organic farming display greater microbial diversity and better structuring, which favors the retention of available water and the availability of nutrients (Song et al., 2023; Lin et al., 2026). On the other hand, the slower mineralization of organic nutrients and the absence of conventional phytosanitary protection can affect plant growth and amplify the susceptibility to diseases, leading to a depreciation of yields and the commercial status of fruits (Chou et al., 2025).

Besides, other elements that change strawberry quality are the presence of physiological abnormalities like albinism or malformed berries often resulting from mineral imbalances, environmental stresses, and inadequate pollination. These aberrations have a large impact on the commercial value of the fruit, and they typically become more pronounced under stressful conditions, particularly in a biological context (Hurtado et al., 2026). Conversely, combating the main diseases, in particular those caused by Botrytis cinerea, is still an important focus of production system practices and requires the implementation of an integrated strategy that integrates cultural factors, variety selections and effective management options (Romanazzi et al., 2016).

In this context, the genetic situation constitutes a preponderant factor in the response of plants to their cultivation regime. Strawberry varieties, in fact, show great variability in terms of vigor the ability to use nutrients, as well as tolerance to biotic or abiotic stresses. The varieties, such as cv. Fortuna, are distinguished by their high productivity and a certain tolerance to diseases, unlike others, such as cv. Llosana may be more sensitive to certain environmental constraints. The study of the interactions between cultivation systems and varieties is therefore essential to identify the optimal combinations to improve agronomic performance and fruit quality (Mazzoni et al., 2020; Chou et al., 2025).

In this context, the objective of this work is to compare the effects of two organic and conventional cultivation methods on the growth, yield, and fruit quality parameters of two strawberry varieties. The comparison will be made through the examination of agronomic indicators (fruit weight, number of fruits, overall and marketable yield) on the one hand, and taking into account anomalies (albinism, malformations), and diseases, including *B. cinerea*, on the other hand. This approach makes it possible to evaluate the productive performance of both the systems and the sustainability and quality of production.

MATERIEL AND METHODS

Preparation of plant material and samples

Two systems of cultivation for strawberries (*Fragaria* x *ananassa* cv. Llosana and Fortuna) planted in October 2024 were compared at the level of Ouled Aguil (Moulay Bousselham, province Kenitra) (34° 51′ 41″ N 6° 9′ 56″ W). The two Spanish cultivation systems are an aboveground biological test and a conventional greenhouse test. A greenhouse is equipped with plastic mulching, drip irrigation, fertilization based on the analysis of organic and mineral soils, and a phytosanitary system that tends towards the levels recommended in the conventional system on sandy soil (pH 6.52). Using just sheep dung vermicompost as fertilizer, organic plants are grown in pots without the need of greenhouses or pesticides. To guarantee a trustworthy distinction between agronomic and qualitative performances, the two experiments with comparable pedoclimatic settings were evaluated at comparable maturity stages and under comparable storage and transportation circumstances (Lamdardar et al., 2025).

Soil analysis

Soil samples were taken from each subplot, at a depth of 0 to 20 cm (main root zone), then homogenized to constitute a composite sample (≈ 1 kg) by repetition and by system (Reganold et al., 2010). The samples are placed in clean bags, labeled, transported to the laboratory, and air-dried.

The dried soils are sieved to 2 mm and stored at 4 °C, then pH and electrical conductivity are determined (Buragienė et al., 2024). Organic carbon and total nitrogen (C, N) by the Kjeldahl method; assimilable phosphorus and potassium, calcium, magnesium, and trace elements by appropriate extraction and then determination (ICP OES/AAS); possibly microbial biomass, basal respiration, and enzymatic activities (phosphatases, dehydrogenase) to characterize the biological quality of soils (Reganold et al., 2010).

Observations recorded

Ripe strawberries were harvested from each system and weighed. After that, the length and width of the fruits were measured using a caliper, as well as the number of fruits per plant, number of leaves per plant. The total yield was calculated taking into account all the harvested fruits. The fruits free from wounds, albinism and malformations, as well as those presenting symptoms of gray rot (*Botrytis cinerea*), were sorted in order to calculate the marketable yield. The incidence of albinism and fruit malformations was determined by counting all albino, malformed and normal fruits, and expressed as a percentage (Singh et al., 2007). Likewise, the incidence of gray rot (*Botrytis cinerea*) was determined by counting all healthy and infected fruits, and expressed as a percentage.

Proximate and mineral analysis

According to Aouji et al. (2024), the method used to determine the relative humidity is based on the sample mass loss until a constant mass is reached at 105 °C. The process of determining the percentage of dry matter (MS) involves placing the sample in an oven at 70 °C until a difference of at least 3 mg between two consecutive samples taken separately at intervals of two hours is obtained (AOAC, 2010). The pH was measured using the procedure described by Brunetti et al. (2019). Additionally, the acidity was determined by titrating the acidity with a 20% sodium hydroxide solution (NaOH) in the presence of a color indicator (phenolphthalein) (Benahmed-Djilali et al., 2017). With the use of a refractive index (ISO 2173, 2003), a drop of liquid is applied and placed on the instrument; the measurement is then read to determine the Brix value.

The average total protein was calculated using the AOAC method 928.08 (AOAC, 2000). All values for total protein were published as grams of protein per 100 grams of dry weight. The protein value was determined by converting nitrogen content into protein using a Jones factor of 6.25. The average lipid content was determined using the Soxhlet method, and values were obtained in g/100 g wet weight. The carbohydrate amount was calculated using the total dry matter minus the amount of fat, protein, and ash (Nannu et al., 2014).

During the calcination experiment two samples each weighing 2 g of the original material were placed in a furnace (800 °C) over 16 hours to determine the mineral components of the ash. The resultant ash product from each sample was mixed with 1/4ths concentrated (12.5M) nitric acid and filtered. This resulting extract was then analysed for trace minerals. Trace minerals were determined using the inductively coupled argon plasma atomic emission spectrophotometer using the following conditions: RF Power=1500 W; Flow rate (Ar)=8 L/min; Auxiliary Flow rate (Ar)=0.2 L/min; Axial, Copied Time=45 minutes; Copied/Playback Time=15 minutes (Aouji et al., 2023a).

Preparation of extracts

First, the fruits must be harvested at the earliest stage of maturity, discarding those that are too young or too old. The fruits are cleaned of any impurities by washing them in distilled water. Then, with the help of a cutter, it was weighed at least 50 grams. After that, a mixture with 100 milliliters of distillated water is made till a homogenous purée is obtained. The obtained juice is next filtered through stainless steel to remove the solid particles. Next, it is placed within hermetically sealed, stylized, and glass flacons (Lamdardar et al., 2025).

Chemical composition

Gas chromatography–mass spectrometry was used to examine the extracts of two variety of strawberry under the following circumstances: the temperature at the injector port was 250 °C. The oven was initially set at 40 °C, and over the course of 18 minutes, the temperature was progressively raised by 8 °C every minute until it reached 260 °C. We made use of the BR-5 ns FS capillary column. The helium injection volume in the undivided mode was 1.0 mL/min. The analysis took 70 minutes in total. The mass spectrometry detector (MSD) was configured for electronic impact ionization, with a scan range of 50 to 500 *m/z* and an ionizing energy of 70 eV. The temperature of the ion source tripled to 150 °C after initially rising to 230 °C. The electron multiplier voltage (EM voltage) was maintained at 1100 V above the self-regulatory threshold with a solvent delay of 3 minutes (Aouji et al., 2024).

Quantification of bioactive contents

With certain adjustments, the Folin-Ciocalteu method described by Aouji et al. (2023 b) was used to determine the total content in phenol. On the other hand, Zirari et al. (2024) estimated the total flavonoid content using the $AlCl_3$ method. Furthermore, the method Lamdardar et al. (2025) that uses pH differences enables a quick and accurate measurement of the total anthocyanins.

Antioxidant activities

Total antioxidant capacity (TAC)

Following the addition of 50 μL of each extract to 2000 μL of the reagent mixture containing (0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdenum) and incubation at 95 °C for 90 minutes, the absorbance was measured at 695 nm using a blank and ascorbic acid to represent an antioxidant. The overall antioxidant ability of the extract was reported as ascorbic acid equivalents per gram dry mass (mg EAA/g DM) (Aouji et al., 2024).

Free radical scavenging activity (DPPH)

A set of tubes containing 50 μL of ethanol solutions containing a concentrated extract will each have 1950 μL of DPPH solution (0.024 g/L fractionally separated) added to them before being mixed well and allowed to react at room temperature for thirty minutes. After the thirty (30) minute reaction period, the absorbance of each sample will be measured at 515 nm and compared against the absorbance of a control. A negative control was prepared by mixing 50 μL of ethanol with 1950 μL of DPPH solution (Lamdardar et al., 2025). Equation 1 has been used to calculate the percentage of inhibition.

$$\%\ Activity\ = \frac{Abs\ Cn - Abs\ Ech}{Abs\ Cn} \times 100 \qquad (1)$$

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

Ferrous ion reducing antioxidant power assay (FRAP)

Pearly Prussian blue production at 700 nm was used to quantify the formation of the ferrous form of the iron/ferricyanide complex (Aouji et al., 2024). For 20 minutes, 200 μL of extracts with different concentrations were mixed with 250 μL of phosphate buffer (0.2 M, pH = 6.6) and 250 μL of potassium ferricyanide (1%, w/v) at 50 °C. After adding 2500 μL of TCA (10%, w/v), the mixture was centrifuged for 10 minutes at 3000 rpm. 500 μL of ferric chloride (0.1%, w/v), 2500 μL of distilled water, and 2500 μL of supernatant were combined. At 700 nm, the absorbance was measured in relation to the negative control. For the L-ascorbic acid standard solution, the same process was used. The reduction of activity can be calculated using the following equations:

$$\%\ Reduction\ power = \frac{(Asample - Ablank)}{Asample} \times 100 \quad (2)$$

where: A_{blank} – absorbance without sample and
A_{sample} – absorbance of the sample.

Analysis of sugars by ion chromatography

The methodology established by Yu et al. (2016) was used to quantify glucose, saccharose, and fructose using ionic chromatography. The separations were carried out using a Dionex CarboPac PA10 anion exchange column. 18 mM sodium hydroxide (NaOH) solution was used as a phase mobile, administered in an isocratic manner with a 1.0 mL/min error. The column's temperature was consistently maintained at 32 °C, and the injection volume was set at 20 μL. The detection was made possible via an amperometries pulse detector (also known as a pulsed detection amperometries, or PAD). Under these particular circumstances, the three saccharides (glucose, saccharose, and fructose) were separated and quantitatively assessed in less than eighteen minutes.

Antimicrobial assays

Bacterial strains

The antibacterial properties have been determined against *S. aureus*, *L. monocytogenes*, *B. subtilis*, *E. coli*, *P. aeruginosa*, *Salmonella* sp. One milliliter of preserved bacterial suspension and two milliliters of nourishing broth were combined to produce live, cultivable bacteria.

Antibiotics

The antibiotics used were Gentamicin (10 µg), Chloramphenicol (30 µg), Ampicillin (10 µg), Ciprofloxacin (5 µg).

Disc diffusion method

Wathman N°3 paper disks (6 mm) were sterilized, boiled for 30 minutes to eliminate any chemical that would prevent microbial development, and then kept in securely sealed sterile glass vials until needed. Antibiotic disks were then put on the surface of the MH medium, which had been pre-inoculated by swabbing with bacterial suspensions (10^8 CFU), after each disk had been coated with varying amounts of slime. After that, the infected Petri plates were incubated in the dark at 37 °C. The diameter of the inhibitory zones, expressed in millimeters, was assessed 24 hours after incubation. In order to use the latter, the bacteria have been categorized (Aouji et al., 2024).

Statistical analysis

Using one-way ANOVA and Tukey's test for comparisons, all statistical analysis was performed using SPSS software version 27 and a significance level of 0.05. The mean of 3 replicates will be presented. Statistical significance will be established at $p<0.05$.

RESULTS AND DISCUSSION

Soil analysis

The soil analysis carried out revealed significant variations in several parameters. The contents of organic matter, total nitrogen and major mineral elements differ according to the cultivation system. Regarding the organic status, the biological system has an organic matter content of 1.85%, more than double that observed in the conventional system (0.71%). This trend is confirmed for organic carbon (1.07% against 0.41%). The C/N ratio, an indicator of the mineralization dynamics, is lower in the biological system (11.0) than in the conventional (13.76). At the level of soil chemistry, the pH measures a neutrality for the biological system (6.98) while the conventional system tends towards acidity (6.52). The electrical conductivity remains low and similar for the two modes (< 0.20 mS/cm). Nutrient analysis shows comparable and high phosphorus levels (>150 mg/kg) in both systems. Potassium is slightly higher in the biological system (62.4 mg/kg) compared to the conventional system (54.8 mg/kg). On the other hand, a notable difference is observed for Magnesium, qualified as low in the biological system while it reaches 42.6 mg / kg in the conventional system. Finally, the trace element concentrations are systematically higher in the conventional system, with particularly marked differences for iron (69.68 vs 15.10 mg/kg) and manganese (35.70 vs 5.30 mg/kg).

A soil rich in organic matter and balanced in nutrients improves the bioavailability of the mineral elements necessary for the synthesis of proteins, sugars and phenolic metabolites. Therefore, the differences observed in the nutritional and chemical composition of the plant extracts can be attributed, in part, to the characteristics of the soil. According to Gaskell et al. (2008), a high organic matter content favors a slow and regular mineralization of nutrients, avoiding the water dilution effect often caused by synthetic nitrogen fertilizers. This explains the higher dry matter and ash content observed in the 2 varieties in organic mode.

The pH of the biological soil is close to neutrality (6.98), while the conventional soil is more acidic (6.52). Although conventional soil displays higher levels of certain trace elements such as iron (69.68 mg/kg) and manganese (35.70 mg/kg), their absorption can be disrupted by chemical imbalances linked to synthetic inputs. On the other hand, the lower C/N ratio in biological mode (11.0 compared to 13.76 in conventional mode) suggests a more intense microbial activity and a better decomposition of organic matter (Table 1).

Effects of cropping systems on agronomic performance

The agronomic performances of the Llosana and Fortuna varieties showed significant differences between the 2 systems (Table 2).

Table 1. Physicochemical characteristics of the soil

Parameters analyzed	Biological	Conventional
Organic status		
Organic matter (%)	1.85	0.71
Organic carbon (%)	1.07	0.41
Ratio C/N	11.0	13.76
Soil chemistry		
pH	6.98	6.52
Electrical conductivity (mS/cm)	0.18	0.19
Total limestone (%)	-	0.94
Nutrients (mg/kg)		
Phosphorus	159.0	165.6
Potassium	62.4	54.8
Magnesium	Low	42.6
Trace elements (mg/kg)		
Iron	15.10	69.68
Manganese	5.30	35.70
Copper	0.40	0.66
Zinc	1.40	1.88

Our results highlight a significant effect of the cultivation system on the agronomic performance of the two strawberry varieties studied. Overall, the conventional system significantly improves the growth and yield parameters. The average weight of the fruits is significantly higher in conventional conditions, reaching 34.35 ± 3.99 g for Llosana and 35.38 ± 1.93 g for Fortuna, against respectively 25.35 ± 2.02 g and 26.92 ± 0.94 g in biological system. This trend is also observed for the dimensions of the fruits (length and width), suggesting a positive effect of mineral fertilization on the caliber of the fruits. Moreover, the number of fruits and leaves per plant is higher in conventional systems, reflecting a more intense vegetative growth and a better productive capacity.

This improvement in the growth parameters is directly reflected in the total yield, which is almost doubled in a conventional system for both varieties. In fact, the Llosana variety reaches 806.33 ± 10.26 g in conventional versus 480.33 ± 13.61 g in organic, while Fortuna goes from 538.00 ± 17.06 g to 883.33 ± 13.20 g. In addition, the marketable yield is also higher in conventional systems, indicating a greater proportion of fruits meeting the marketable quality criteria. These findings confirm that immediate access to nutrients and phytosanitary protection provided by conventional systems enhances the commercial quality and productivity of the fruits produced.

The biological system is also associated with an increase in the occurrence of physiological abnormalities and disease. The rates of albinism are significantly higher within the biologically grown conditions when compared to conventionally produced fruits with percentages of 31.82 ± 6.95% (Llosana) and 31.09 ± 2.76% (Fortuna) in comparison to 18.87 ± 1.61% (Llosana) and 11.15 ± 3.97% (Fortuna), respectively, for conventionally produced fruits.

There are also differences between cultivars. In conventional growing systems, the Fortuna cultivar yields a greater total product than Llosana; however, Fortuna is also more susceptible to diseases such as *Botrytis* than the Llosana cultivar is. Conversely, Llosana is characterized by a higher level of agronomic stability than Fortuna cultivars

Table 2. Growth parameters, yield and incidence of anomalies and diseases

Parameters	Llosana		Fortuna	
	Biol treat	Conv treat	Biol treat	Conv treat
Average Weight (g)	25.35 ± 2.02^{a}	34.35 ± 3.99^{b}	26.92 ± 0.94^{a}	35.38 ± 1.93^{b}
Length (mm)	44,15 ± 5,44^{ab}	57,34 ± 9,37^{b}	32,66 ± 5,44^{a}	43,38 ± 0,97^{ab}
Width (mm)	33,80 ± 2,31^{a}	45,65 ± 4,03^{b}	24,53 ± 2,31^{c}	36,92 ± 1,07^{a}
Fruits/plant	19.00 ± 1.00^{a}	23.67 ± 2.52^{bc}	20.00 ± 1.00^{ab}	25.00 ± 1.00^{c}
Leaves/plant	18.33 ± 3.51^{a}	23.67 ± 4.73^{a}	19.67 ± 3.51^{a}	27.67 ± 3.79^{a}
Total Return (g)	480.33 ± 13.61^{a}	806.33 ± 10.26^{a}	538.00 ± 17.06^{c}	883.33 ± 13.20^{d}
Marketable yield (%)	47.86 ± 3.91^{a}	57.77 ± 5.40^{ab}	58.14 ± 3.91^{ab}	65.45 ± 2.97^{b}
Albinism (%)	31.82 ± 6.95^{a}	18.87 ± 1.61^{b}	31.09 ± 2.76	11.15 ± 3.97^{b}
Malformations (%)	9.92 ± 1.86^{c}	1.69 ± 0.37^{ab}	4.23 ± 0.64^{b}	0.00 ± 0.00^{a}
Botrytis (%)	15.31 ± 2.38^{a}	3.38 ± 0.41^{b}	9.38 ± 1.21^{c}	1.80 ± 0.36^{b}

Note: Conv treat – conventional treatment; Biol treat – biological treatment. The significant difference ($p<0.05$) between the different extracts is illustrated by the letters a and b.

and has somewhat lower rates of abnormal issues. This reinforces that the response of the cultivar to various cropping systems depends on their agronomic practices as well as their genotype, thus highlighting the importance of cultivar selection to optimize yield based on production methods.

Our results confirm that the conventional system significantly improves the growth and yield of strawberries, which is consistent with the work of Reganold et al. (2010) and Ombita et al. (2024), which showed that the immediate availability of mineral nutrients promotes vegetative development and fruit filling. The increase in average weight and total yield observed in this study can be attributed to a better assimilation of nitrogen, phosphorus and potassium, essential elements for fruit production (Yasir et al., 2025). On the other hand, the biological system, although it contributes to the improvement of soil quality and microbial activity (Lori et al., 2024), presents limitations in terms of yield due to slower mineralization of nutrients.

The higher incidence of *Botrytis cinerea* and physiological abnormalities in the biological system is in agreement with the observations of Romanazzi et al. (2016) and Petrasch et al. (2019), which indicate that the absence of fungicidal treatments favors the development of pathogens, especially in conditions of high humidity. However, the differences observed between the varieties confirm the importance of the genetic factor in the stress response, as reported by Skrovankova et al. (2015). The Llosana variety thus appears to be more efficient in terms of yield, while Fortuna shows an increased sensitivity to diseases, especially under biological conditions. Therefore, these findings emphasize the need to develop an integrated production system that considers varietal selection, as well as agronomic and horticultural practices, to improve yield and fruit quality for different production systems.

Proximal composition

Several statistically significant differences were noted between the two treatments based on their proximal composition (Table 3). The use of biological treatment improved the dry weight of both varieties, increasing from 9.04 ± 0.12% to 9.61 ± 0.16% for Llossana and from 8.95 ± 0.15% to 9.59 ± 0.22% for Fortuna. These data indicate that fruits produced with organic techniques exhibit an overall greater amount of solids, positively impacting their organoleptic characteristics. The results from this study correlate with previous findings by Caris-Veyrat et al. (2004), who documented substantially increased numbers of solids in fruit produced using biological agricultural systems as well. The majority of these discrepancies have been attributed as a result of the slower growth of the organic system as well as the slower release of nutrient & water over time.

From a nutritional point of view, biological treatment seems to favor the accumulation of macronutrients. A significant increase in the protein content is observed, which reaches 0.94% under biological diet against 0.81% in conventional for both genotypes. Likewise, soluble sugars and

Table 3. Proximate composition

Parameters	Llossana		Fortuna	
	Conv treat	Biol treat	Conv treat	Biol treat
WC (%)	92.08 ± 0.05 ^{a}	91.3 ± 0.31 ^{bc}	91.65 ± 0.17 ^{ab}	90.96 ± 0.23 ^{c}
DM (%)	9.04 ± 0.12 ^{a}	9.61 ± 0.16 ^{b}	8.95 ± 0.15 ^{a}	9.59 ± 0.22 ^{b}
A (%)	0.61 ± 0.06 ^{a}	0.71 ± 0.07 ^{a}	0.69 ± 0.04 ^{a}	0.78 ± 0.08 ^{a}
pH	3.63 ± 0.05 ^{a}	3.54 ± 0.04 ^{a}	3.59 ± 0.02 ^{a}	3.51 ± 0.05 ^{a}
Ss (°Brix)	6.83 ± 0.04 ^{a}	7.15 ± 0.05 ^{b}	6.16 ± 0.06 ^{c}	6.46 ± 0.05 ^{d}
P (%)	0.81 ± 0.02 ^{a}	0.94 ± 0.03 ^{a}	0.77 ± 0.03 ^{a}	0.95 ± 0.04 ^{a}
Cf (%)	0.39 ± 0.03 ^{a}	0.45 ± 0.05 ^{a}	0.37 ± 0.03 ^{a}	0.45 ± 0.05 ^{a}
Carb (%)	7.26 ± 0.09 ^{a}	7.38 ± 0.20 ^{a}	7.17 ± 0.13 ^{a}	7.37 ± 0.26 ^{a}
Ac (%)	0.58 ± 0.01^{a}	0.84 ± 0.04 ^{b}	0.51 ± 0.03^{a}	0.84 ± 0.05 ^{b}
E (Cal/100 g)	35.79 ± 0.65 ^{a}	37.40 ± 0.92 ^{a}	35.63 ± 0.48 ^{a}	37.32 ± 1.08 ^{a}

Note: Conv treat – conventional treatment; Biol treat – biological treatment; WC – water content; DM – dry matter; A – acidity; Ss – soluble sugar; P – protein; Cf – crude fat; Carb – carbohydrate (%); Ac – ash content; E – energy. The significant difference ($p<0.05$) between the different extracts is illustrated by the letters a and b.

total carbohydrates show higher values in the samples from organic farming. Finally, the ash content showed a particularly marked increase in the Fortuna variety, climbing from 0.58 ± 0.01% to 0.84 ± 0.04% under the influence of biological treatment.

This outcome is consistent with the findings of Reganold et al. (2010), who noted that in response to moderate levels of environmental stress, organic agriculture techniques promote the economic allocation of soluble molecules, such as sugars. The same models were also mentioned by Woese et al. (1997), who contended that the mild stress that organic farming frequently experiences might be advantageous by boosting the accumulation of proteins and other primary metabolites.

Although the changes are not always statistically significant, these results are consistent with a comparatively large body of scientific research that suggests the organic production technique might enhance the nutritional composition of fruits (Brandt and Mølgaard, 2001; Lairon, 2010). The primary environmental elements that affect the nutritional makeup of plants growing in various locations are soil fertility, moisture content, and growth temperature.

Mineral composition

The results show that the biological treatment selectively modifies the mineral composition of the samples, with consistent effects between the two varieties. For the microelements, calcium, magnesium and chlorine do not show any significant difference between the 2 treatments (*p<0.05*), indicating that these elements remain relatively stable regardless of the treatment mode. On the other hand, sodium increases significantly under biological treatment, particularly in Llossana, suggesting a modification of the mechanisms of ionic absorption or retention. Potassium decreases sharply and significantly in both varieties, probably reflecting an alteration in the dynamics of the major cations. Similarly, phosphorus shows a significant reduction under biological treatment, which could reflect a variation in the availability or mobilization of this element.

Iron has been found to be unchanged statistically with the different treatment levels, indicating no change in the accumulation of iron due to treatment. There is a small amount of variance in the amount of manganese that accumulates; in the case of the Fortuna variety, manganese slightly decreased with the biological treatment, while its accumulation for the felsaceae family was relatively unaffected by the biological treatment. However, there was a considerable increase in zinc and copper for both varieties when treated with biological material, suggesting the treatments of these elements will result in either or both of the biological availability of zinc and copper or their metabolic assimilation. Furthermore, the increase in the amounts of zinc and copper, both of which are involved in numerous enzyme systems, would be expected to have significant functional implications for both physiological processes and oxidative processes.

The biological treatment alters the mineral profile of water, which results in decreased levels of potassium and phosphorus (primary elements responsible for osmotic and energy balance) and increases the concentration of trace elements such as zinc and copper. This redistribution of minerals could represent some type of change in either soil-plant relationships, or the mechanisms of transport across membranes. Because the effects from Llossana and Fortuna have the same trends, but may differ in magnitude by variety, it appears that response is closely related to the application method rather than to genetic variability. As well, these results confirm that treatment method is critical in modifying mineral composition (Table 4).

According to a study by Rembiałkowska (2007), goods from organic farming, especially those cultivated on well-amended soils with compost, have much higher concentrations of certain minerals than their conventional equivalents. These findings imply that absorption mechanisms are influenced by uneven fertilization and the bioavailability of nutrients in organic soils. These findings are supported by Mäder et al. (2007), who emphasize that the kind of fertilizer applied in organic farming might affect the trace element concentration of plants.

Chemical composition

Analysis by gas chromatography coupled with mass spectrometry (GC-MS) made it possible to highlight substantial differences in the volatile chemical composition of strawberry fruits. A proportion of 87.44% and 74.09% of the total chromatographic surface could be attributed to compounds identified respectively in the biological and conventional systems. The remaining fraction corresponds to unidentified compounds, which reflects the intrinsic complexity of the

Table 4. Minerals content of conventional and biological treatment

Parameters	Concentration (mg.kg^{-1})			
	Llossana		Fortuna	
	Conv treat	Biol treat	Conv treat	Biol treat
Calcium	190.67 ± 3.79 ^{a}	180.67 ± 3.51 ^{a}	188.67 ± 7.37 ^{a}	179.33 ± 10.69 ^{a}
Sodium	2.16 ± 0.07 ^{ab}	2.35 ± 0.03 ^{c}	2.12 ± 0.09 ^{a}	2.32 ± 0.02 ^{bc}
Potassium	1818.00 ± 6.56 ^{a}	1435.00 ± 7.00 ^{b}	1811.33 ± 3.21 ^{a}	1426.33 ± 11.59 ^{b}
Magnesium	171.33 ± 2.52 ^{a}	168.00 ± 7.55 ^{a}	168.00 ± 4.36 ^{a}	169.33 ± 8.74 ^{a}
Iron	0.51 ± 0.06 ^{a}	0.61 ± 0.07 ^{a}	0.48 ± 0.06 ^{a}	0.57 ± 0.06 ^{a}
Manganese	0.59 ± 0.02 ^{a}	0.55 ± 0.04 ^{ab}	0.54 ± 0.02 ^{ab}	0.53 ± 0.01 ^{b}
Zinc	3.64 ± 0.17 ^{a}	5.86 ± 0.10 ^{b}	3.63 ± 0.25 ^{a}	5.87 ± 0.07 ^{b}
Copper	2.32 ± 0.04 ^{a}	2.88 ± 0.14 ^{b}	2.29 ± 0.04 ^{a}	2.87 ± 0.09 ^{b}
Phosphorus	270 ± 7.94 ^{a}	230 ± 3.61 ^{b}	267.33 ± 6.81 ^{a}	227.67 ± 5.51 ^{b}
Chlore	7.63 ± 0.03 ^{a}	7.72 ± 0.05 ^{a}	7.60 ± 0.07 ^{a}	7.69 ± 0.06 ^{a}

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

aromatic profile of the strawberry. The results reveal a clear divergence between the two cultivation systems in terms of the distribution of chemical families. The conventional system is mainly characterized by a dominance of esters, while the biological system presents a marked accumulation of furanones and fatty acids.

The majority of strawberries from an organic system are made up of esters. The most common esters in strawberries from the conventional system are ethyl acetate (23.49% of total volume), ethyl butyrate (3.82% of total volume), methyl butyrate (0.88% of total volume), methyl hexanoate (4.48% of total volume), isoamyl acetate (1.01% of total volume) and butyl acetate (0.54% of total volume) (Pérez et al., 1997). Each of these molecules contributes to strawberry's characteristic fruity, fresh and sweet aroma. The increased ester content in process strawberry products can be attributed to higher levels of activity of the alcohol-acyltransferase enzymes that play a key role in the production of esters via the biochemical pathway known as esterification, which is frequently stimulated by mineral fertilization and increased availability of nitrogen (Aharoni et al., 2004; Schwieterman et al., 2014) (Table 5).

Conversely, strawberries produced under the biological system have a volatile profile dominated by furanones. Furaneol represents 30.22% of the total volatile fraction, while mesifuran reaches 15.47%. These compounds are considered to be key determinants of the aromatic quality of the strawberry, conferring caramel, sweet and ripe fruit notes (Zabetakis and Holden, 1997). Their significant accumulation in biological culture suggests an orientation of metabolism towards the pathways of secondary metabolism. This dynamic can be explained by the gradual release of nutrients from organic fertilization and by moderate stress conditions favoring the degradation of sugars and the formation of complex aromatic metabolites (Klee and Tieman, 2013) (Figure 1).

There are also considerable differences in the fatty acid contents of both systems. The organic systems are high in long-chain fatty acids, particularly 9,12,15-octadecatrienoic acid (18.99%) and n-hexadecanoic acid (4.10%). These compounds are important as metabolic precursors in the synthesis of aroma compounds and indicate a higher level of lipid synthesis activity (Schwab et al., 2008). Conversely, the conventional systems contain lower amounts of fatty acids, suggesting that production is shifted towards esters instead of accumulating lipids.

With regard to terpenes and lactones, linalool (8.24%) and γ-decalactone (1.13%) are primarily present in the conventional system and produce floral and creamy notes. Their presence enhances the fresh, attractive aroma of conventional fruit. Overall, the difference in aroma characteristics implies that the conventional system favors compounds associated with fresh aroma and perceived freshness, while the organic system favors compounds associated with maturity and more complex aromas.

Different concentrations of alcohols and aldehydes occur in different growing systems, but both groups of compounds are present in both

Table 5. Chemical composition by GC-MS

Compounds Name	Biol treat		Conv treat	
	RT (min)	%	RT (min)	%
Acetaldehyde	-	-	3.281	1.44
Propanal	-	-	3.627	1.61
Ethyl butyrate	-	-	4.094	3.82
Ethyl acetate	4.069	2.41	4.804	23.49
Methyl butyrate	-	-	5.067	0.88
Butyl acetate	-	-	6.642	0.54
Ethyl pentanoate	-	-	7.126	0.75
(Z)-3-Hexenol	-	-	8.273	0.342
Isoamyl acetate	-	-	8.86	1.01
Hexanol	-	-	10.5	2.09
Butyl butyrate	-	-	12.493	0.381
Methyl hexanoate	-	-	12.871	4.48
Methyl acetate	4.473	0.91	-	-
2,5-dimethyl-4-hydroxy-3(2H)-furanone	4.707	30.22	31.214	0.06
2,4-Dihydroxy-2,5-dimethyl-3(2H)-furanone	6.626	0.94	-	-
Dimethylamine	7.145	2.16	-	-
2-Pentanone	8.85	1.39	-	-
Mesifurane	14.085	15.47	14.841	14.841
Butyl hexanoate	-	-	15.158	2.08
Ethyl octanoate	-	-	15.465	2.21
Linalool	19.283	2.64	17.873	8.24
Benzaldehyde	-	-	19.043	0.37
Benzyl alcohol	-	-	19.961	1.27
Phenethyl alcohol	-	-	20.129	0.36
(Z)-7-Tetradecene	23.45	0.16	-	-
Hexanoic acid	-	-	25.643	0.37
Octanoic acid	-	-	30.806	0.09
Nerolidol	-	-	32.656	0.05
γ-Decalactone	-	-	43.379	1.13
Phytol	36.149	0.49	-	-
Octadecanal	42.221	0.22	-	-
n-Hexadecanoic acid	43.435	4.1	-	-
Oleic acid	46.893	0.48	48.031	0.99
Linoleic acid	47.034	0.77	48.178	0.85
Linolenic acid	47.376	0.54	48.298	0.27
9,12,15-Octadecatrienoic acid	48.326	18.99	-	-
3-Methoxybenzaldehyde	61.053	0.14	-	-
α-Tocopherol	67.30	0.43	-	-
β-Sitosterol	69.636	0.37	-	-
Dodecanoic acid	43.435	4.10	46.866	0.044
Vanillin	36.149	0.494	38.121	0.03
Identified	-	87.424	-	74.088
Not identified	-	12.576	-	25.912

Note: Conv treat – conventional treatment; Biol treat – biological treatment.

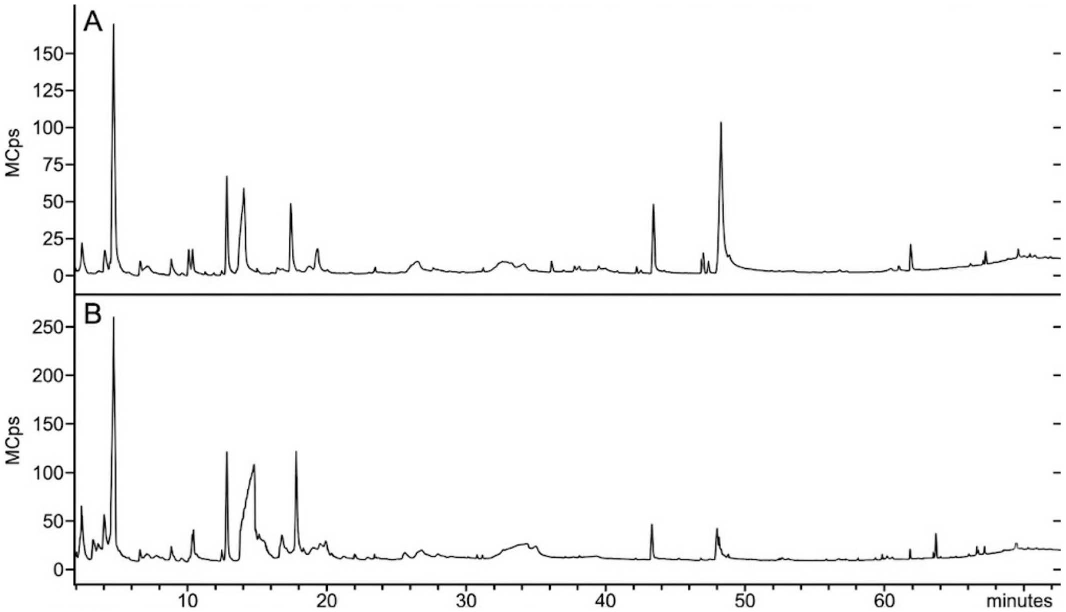

Figure 1. Chromatograms: (a) biological system; (b) conventional system

systems. Acetaldehyde and propanal were only found in samples from the conventional growing system, while some short-chain alcohols were detected in higher concentrations in organic cultivation. These differences indicate that there are differences in the activation of various enzymatic pathways, mainly the lipoxygenase pathway which is often affected by environmental and physiological factors.

Overall, these data support the idea that the type of culture system used plays an important role in determining how plant metabolism occurs, and therefore the differences in the types of volatile chemicals that can be produced by strawberry plants. The conventional culture system produces large quantities of esters and therefore produces strawberries that have a very strong fruit-like aromatic profile. The traditional culture system produces strawberries that contain high amounts of furanones and fatty acids and therefore produce strawberries with a more complex, sweet, and characteristic "berry" aroma. Overall, these findings highlight the impact of cultural practices in determining the feel and chemical quality of fruits.

Marked quantitative differences have been observed between the two systems, indicating a strong influence of cultural practices on the metabolic pathways involved in the formation of aromas (Forney et al., 2000; Schwab et al., 2008).

Quantitative phytochemical analysis

Quantitative analysis reveals that cultivation practices significantly influence the biosynthesis of phenolic compounds in strawberry trees. In general, the biological treatment favors a greater accumulation of these molecules compared to the conventional treatment for the two varieties studied (Figure 2). The significant increase in total polyphenols, reaching 187.33 ± 3.51 mg/g for the Fortuna variety and 168.33 ± 5.03 mg/g for Llossana, suggests an activation of metabolic pathways related to plant defense. In the absence of synthetic phytosanitary protection, fruits allocate more carbon resources to the production of phenolic compounds to ensure their protection against biotic stresses, a mechanism in agreement with the hypothesis of carbon-nutrient balance.

The fraction of flavonoids is the one that presents the most plastic response to the change of culture system, with an increase of more than 50% in Fortuna and 36% in Llossana when switching to organic mode. This selective accumulation suggests that environmental stress in organic agriculture preferentially targets the phenylpropanoid pathway. Conversely, the quantitative stability of anthocyanins (25.68 to 28.12 mg/g) indicates that the pigmentation of the fruit is a genetically stable character, less influenced by cultural practices than the other secondary metabolites.

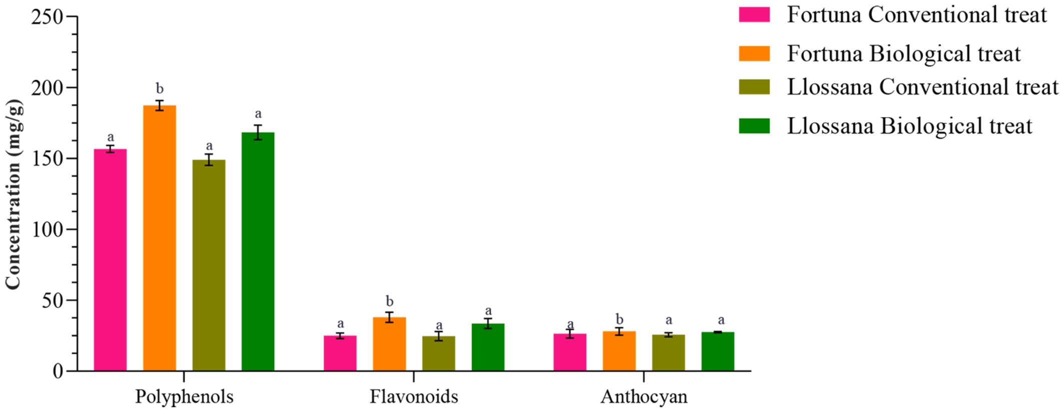

Figure 2. Composition of phenolic compounds of conventional and biological treatment. The significant difference ($p<0.05$) between the different extracts is illustrated by the letters a and b

Finally, although the Fortuna variety displays a quantitatively higher phenolic storage capacity, the Llossana variety shows a more balanced physiological response between its different metabolic fractions. This quantitative inter-varietal difference underlines the importance of the choice of the genotype in organic farming to maximize the nutritional density and the natural robustness of the fruit.

This accumulation of polyphenols and flavonoids in organic farming is often interpreted as an adaptation strategy of the plant. In the absence of synthetic pesticides, plants activate their own defense mechanisms, thus stimulating the production of antioxidant molecules. The differentiated response between Fortuna and Llossana also suggests a genetic factor, where certain genotypes possess a higher metabolic plasticity to respond to changes in cultural practices. These results confirm that the biological treatment not only improves the proximal composition, but also strengthens the density of bioactive compounds with high added value for human health. These increases, which are more commonly seen in systems without chemical inputs, such as mild fungal infections or water fluctuations, are generally understood to be a physiological reaction to certain forms of stress (Brandt et al., 2011). This supports the notion that organic farming increases the expression of secondary metabolic pathways, especially those associated with the plant's natural defenses (Barański et al., 2014). Crecente-Campo et al. (2012) found a relationship between the chemical makeup of strawberries and the agricultural approach; they found that strawberries cultivated using organic methods had higher amounts of anthocyanins. However, there is no discernible variation at the level of total flavonoids. This may indicate that the synthesis of these chemicals is heavily influenced by varietal genetics or that they are less susceptible to variations in the growing technique.

Antioxidant activities

The results of the total antioxidant capacity (TAC) reveal a beneficial impact of the biological treatment for both genotypes. The samples obtained from the biological treatment displayed significantly higher TAC values ($p<0.05$) than those from the conventional treatment. More precisely, the concentration has increased from 0.39 to 0.46 mg EAA/mL for Fortuna and from 0.40 to 0.49 mg EAA/mL for Llossana. These results show that, even when the increase in total phenols is not statistically obvious, case of Llossana, the overall antioxidant effectiveness of the extract is still reinforced by organic practices.

The superiority of the antioxidant capacity in biological samples can be attributed to a synergy between the different secondary metabolites whose biosynthesis is stimulated in the absence of synthetic pesticides. For Llossana, the significant improvement in TAC despite a moderate increase in phenols suggests that biological treatment could influence the production of other antioxidant molecules not measured here, such as vitamin C or certain carotenoids. One of the most notable results is that, although Fortuna accumulates more total phenols, Llossana has the highest total antioxidant capacity in a biological diet (0.49 mg EAA/mL). This indicates that the quality of the antioxidant activity does not depend only on the crude concentration of polyphenols, but probably on a synergy between the secondary metabolites and the increased mineral richness (Figure 3).

The DPPH test was used to determine the ability of the extracts to yield hydrogen atoms to neutralize free radicals, expressed by IC_{50}. A significant decrease in IC_{50} was observed in the extracts resulting from the biological treatment, reflecting an increased antioxidant power. In Fortuna, the IC_{50} was reduced from 2650 mg/mL for the conventional treatment to 2150 mg/mL for the biological system, while for Llossana it was reduced from 2800 mg/mL to 2300 mg/mL. This improvement in the radical scavenging performance is closely linked to the higher concentration of phenolic compounds and anthocyanins identified previously in the biological samples.

The ferric-reducing antioxidant power method (FRAP) test demonstrates how well the extracts are reducing agents by changing from a ferric complex (Fe^{3+}) to ferrous complex (Fe^{2+}). The evaluation of the samples showed that biologically cultivated samples had a greater reducing power than conventionally produced samples with lower IC_{50}. The Llossana variety produced in organic conditions exhibited the greatest efficiency for reduction of all the cultivars tested (approximately, 115 mg/mL) and exceeded the results achieved with Fortuna. This significant capacity for reduction through electron transfer supports the premise that organic farming enhances the plant's ability to produce high-redox potential compounds.

While Smith-Spangler et al. (2012) confirm that the organic cultivation method stimulates the plant's defense pathways. Olsson et al. (2006) who observed greater antioxidant activity in organic fruits, attributed to an increased diversity of phenolic compounds due to environmental stress.

Antibacterial assay

Strawberry extracts have a broad spectrum of antibacterial activity as demonstrated by diffusion

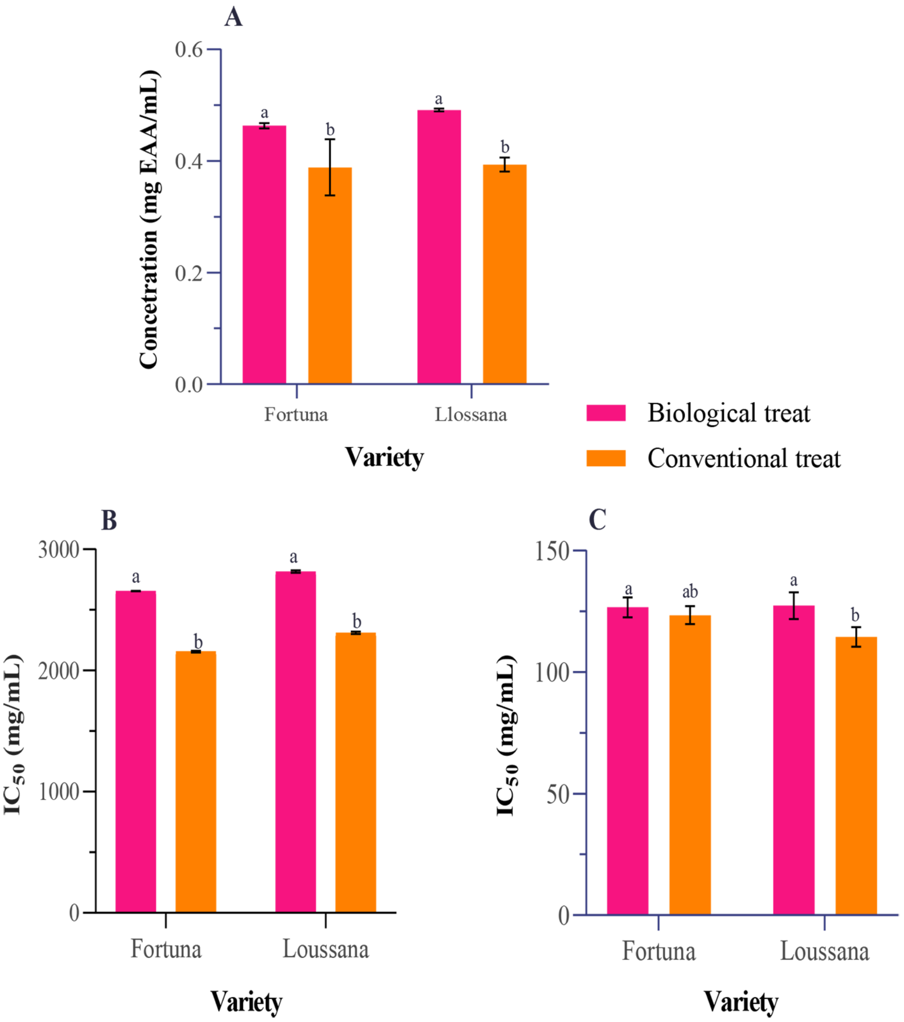

Figure 3. Evaluation of the antioxidant activity of conventional and biological treatment: A: TAC; B: DPPH; C: FRAP. The significant difference ($p<0.05$) between the different extracts is illustrated by the letters a and b

tests on agar. The organic cultivation system produced a greater degree of efficacy than the conventional system for the Llossana variety of strawberry with respect to both *L. monocytogenes* (+40.7%) and *E. coli* (+51.2%). For example, the Zone of Inhibition (diameter) for *E. coli* increased from 6.83 mm to 10.33 mm with a change from conventional to organic. While the Fortuna variety exhibited a similar response to the change in growing method, the overall diameter were less than those of the Llossana variety, suggesting that the genotype has an effect on the concentration of antimicrobial agents in each variety.

The comparative analysis shows a more marked sensitivity of Gram-positive bacteria (*S. aureus*, *L. monocytogenes*, *B. subtilis*), whose inhibition diameters in biological mode all exceed the threshold of 10 mm. Conversely, Gram-negative bacteria, and more specifically *P. aeruginosa*, manifest the highest resistance with the smallest inhibition zones (7.00 mm for Llossana and 6.85 mm for Fortuna in biological mode). This variation in effectiveness between the strains emphasizes that if the biological mode maximizes the production of defense molecules, their action remains modulated by the structure of the bacterial cell wall.

The superior antibacterial efficacy observed in biological extracts, especially for the Llossana variety, can be attributed to a synergy between the increased mineral density and the richness in secondary metabolites. In organic farming, the absence of synthetic pesticides induces a natural biotic stress which stimulates the biosynthesis of phenolic compounds and terpenes of defense (Table 6).

The reference antibiotics show significantly wider areas of inhibition than those of the natural samples. Ciprofloxacin exhibits the strongest activity against the majority of strains, in particular Gram-negative bacteria. Conversely, *P. aeruginosa* shows a low sensitivity to ampicillin and chloramphenicol, indicating an expected resistance profile (Table 7).

Table 6. Mean diameter of the pathogen inhibition zones

Pathogen	Diameter (mm)			
	Llossana		Fortuna	
	Conventionnel	Biological	Conventionnel	Biological
S. aureus	9.50 ± 0.50 ^{a}	10.83 ± 0.76 ^{a}	9.20 ± 0.45 ^{a}	10.50 ± 0.60 ^{a}
L. monocytogenes	8.17 ± 1.04 ^{a}	11.50 ± 0.50 ^{a}	7.85 ± 0.90 ^{a}	11.10 ± 0.55 ^{a}
B. subtilis	8.67 ± 0.76 ^{a}	10.67 ± 0.76 ^{a}	8.40 ± 0.70 ^{a}	10.25 ± 0.80 ^{a}
E. coli	6.83 ± 0.29 ^{a}	10.33 ± 1.04 ^{a}	6.50 ± 0.35 ^{a}	9.90 ± 0.95 ^{a}
P. aeruginosa	6.33 ± 0.29 ^{a}	7.00 ± 1.32 ^{a}	6.15 ± 0.40 ^{a}	6.85 ± 1.15 ^{a}
Salmonella sp.	6.50 ± 0.50 ^{a}	9.33 ± 1.04 ^{a}	6.30 ± 0.55 ^{a}	9.15 ± 0.90

Table 7. Average diameter of the zones of inhibition of antibiotics against

Pathogens	Diameter (mm)			
	Gentamicin (10 µg)	Chloramphenicol (30 µg)	Ampicillin (10 µg)	Ciprofloxacin (5 µg)
S. aureus	16.50 ± 0.50 ^{a}	23.00 ± 1.00 ^{a}	25.17 ± 1.26 ^{a}	24.33 ± 0.76 ^{a}
L. monocytogenes	17.50 ± 0.50 ^{a}	23.00 ± 0.50 ^{a}	24.50 ± 0.87 ^{a}	22.83 ± 1.04 ^{a}
B. subtilis	17.33 ± 1.15 ^{a}	25.00 ± 1.00 ^{a}	24.00 ± 2.57 ^{a}	27.33 ± 0.76 ^{a}
E. coli	15.83 ± 1.04 ^{a}	20.50 ± 1.32 ^{a}	16.83 ± 1.04 ^{a}	33.33 ± 2.08 ^{a}
P. aeruginosa	18.33 ± 1.53 ^{a}	6.83 ± 0.76 ^{a}	7.17 ± 1.04 ^{a}	28.50 ± 1.32 ^{a}
Salmonella sp.	19.00 ± 0.50 ^{a}	22.00 ± 1.32 ^{a}	15.17 ± 0.76 ^{a}	31.50 ± 2.00 ^{a}

Note: Means within the same column share the same symbols, they do not differ significantly from one another at the 5% significance level based on Tukey's test.

Sugar composition

Quantitative analysis of simple sugars reveals that fructose and glucose constitute the predominant fraction of soluble carbohydrates for the two varieties studied. A systematic and statistically significant increase ($p<0.05$) of these two monosaccharides is observed under the influence of biological treatment. In the Llossana variety, the

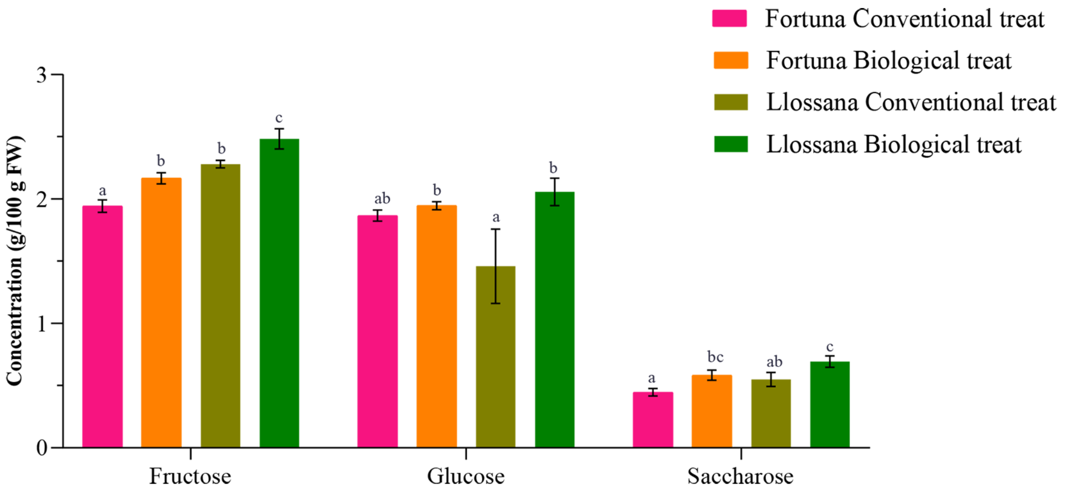

Figure 4. Sugar composition of conventional and biological treatment. The significant difference ($p<0.05$) between the different extracts is illustrated by the letters a and b

fructose reaches its maximum concentration with 2.47 ± 0.08 g/100 g FW in organic mode, against 2.26 ± 0.05 g/100 g FW in conventional mode. An identical trend is observed for glucose, where the transition to organic cultivation induces a notable increase, particularly in Llossana where the values go from about 1.45 g/100 g FW to more than 2.0 g/100 g FW. This increased accumulation of reducing sugars suggests an optimized photosynthetic activity or a specific metabolic response to organic inputs (Figure 4).

According to Pott et al. (2020), plants in an organic diet often accumulate soluble sugars as response mechanisms to environmental variations.

CONCLUSIONS

Our results show that the cultivation system strongly influences the soil properties, agronomic performance and biochemical quality of strawberries. The biological system significantly improves soil fertility, in particular by increasing organic matter and intensifying microbial activity, thus contributing to a better sustainability of agroecosystems. On the other hand, the conventional system favors a higher production thanks to an immediate availability of nutrients and a better control of diseases. Qualitatively, the biological system is distinguished by an improvement in the nutritional and functional composition of the fruits, including an increase in phenolic compounds, antioxidant activity and antibacterial activity. In addition, it induces a modification of the aromatic profile towards more complex compounds, such as furanones, contributing to a better sensory quality. The differences observed between the Llosana and Fortuna varieties also confirm the importance of the genetic factor in the response to growing systems. Thus, an integrated approach combining varietal choice and cultivation practices appears essential to optimize both the yield and the quality of the fruits. In perspective, additional studies integrating multi-environmental analyses and in-depth metabolomic approaches would make it possible to better understand the physiological and biochemical mechanisms involved in the response of strawberry trees to cropping systems.

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