What changes are needed in the diversity of fruit production to ensure healthy, sustainable food?

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The French fruit industry is led by a well-organised profession, producing mainly fresh fruits. This production is in line with societal expectations in terms of quality, nutrition profile, food safety and is increasingly oriented towards the agro-ecological transition. Qualitative and diversified, this production relies on the increasingly well-known Eco-friendly orchards label, which gives consumers confidence and drives purchasing decisions. Nevertheless, the fruit sector is facing difficulties, with its competitiveness subject to imports, rising production costs (labour, energy and inputs) and climatic hazards. In the context of a stagnating fresh fruit consumption, the crisis in purchasing power represents a new threat, leading consumers to look for low prices at the detriment of other attributes, while the organic segment is also stalling. The processed fruit sector is experiencing a more favourable national context, but could progress thanks to efforts to diversify varieties and products, and to capitalize on regional assets. In fresh and processed fruit, the sector is finally experiencing attempts at diversification, responding to the quest for "super-fruits" (e.g., pomegranate), and calling for the establishment of new organisations. Against this contrasting picture, this workshop debated the issue of fruit production diversity in the face of agriculture and food challenges.

Keywords: Fruit sector, consumption, nutrition, quality, labelling.

1. Some background and questions

French fruit production exploits a wide range of climates and terroirs, and is highly diverse in terms of species grown, production systems, varieties and outlets. The quality of French fruit is recognised, often accredited by official labels (SIQO) but also by professional labels (Eco-friendly orchards, § 2.2; Demain la terre, etc.). There is an equally wide range of ways in which products can be sold downstream (supermarkets and fresh produce specialists, short sales channels) or once processed (cf. § 2.3). In terms of species grown, in addition to rosaceous fruits (apples and pears, peaches and nectarines, plums and apricots, cherries), kiwifruits, clementines, table grapes and red fruits, there is an interesting trend in the nuts sector (particularly walnuts, hazelnuts and almonds) (Regnard and Hutin, 2021), while diversification processes are emerging (pomegranate sector, see § 2.4 below).

In response to societal expectations and regulatory requirements, but also out of technical necessity, orchard concepts and practices have constantly evolved, gradually adopting Integrated Fruit Production (IFP) standards from the 1980s onwards. Orchard plots intrinsically make room for plant diversity (border hedges, pollinator varieties, inter-row grassing, ecological compensation areas), and this is often stipulated in the production criteria. Developments in fruit-growing systems have moved away from monoculture, and the quest for plant diversity has led in recent years to the experimentation of prototype systems: orchards made up of a mixture of fruit species (Alto 'Z' project, Simon et al, 2022), agroforestry based on fruit trees and other woody plants (Lauri et al., 2020), market garden orchards (organic farming, Léger et al., 2019), grazed orchards (Pissonnier et al., 2019). In these systems, plant diversity and/or the

complexity of vegetation strata enable the establishment of a biocenosis with multiple interactions, promoting resilience in the face of biotic and abiotic stresses and the emergence of ecosystem services (water, carbon and nitrogen cycles, Demestihas et al., 2019).

Despite these strengths and the technical expertise of those involved in the fruit sector, the French context remains varied, fragile and sometimes worrying: some species are in decline (pear, peach, cherry, table grape), both in terms of surface area and production potential. Analysis of the competitiveness of fruit farms and sectors (FranceAgriMer, 2021) in the face of international competition provides a clear picture of some of the structural handicaps, such as labour costs. Furthermore, consumption of fresh fruit has stagnated or fallen since 2016, at least in volume, despite continuing high levels of confidence (CSA, 2023, study for FranceAgriMer and Interfel). Linked to this observation is the context of the recent crisis in purchasing power, which seems to be putting the price argument back at the centre of consumers' concerns (see Table 1). In March 2022, the French Ministry of Agriculture announced the publication of a sovereignty plan for the fruit and vegetable sector, in line with the wider objectives of the Green France initiative. The outline of this plan, which was announced in early 2023, after the workshop was held, is based on the observation that the self-sufficiency rate for fruit and vegetables fell from 73.6% to 62.7% (excluding citrus fruit, exotic fruit and potatoes) between 2000 and 2020, a loss of 11% over the period. Including citrus fruits and exotics, the 2020 self-sufficiency rate is just over 50% (one fruit or vegetable in two is imported). For fruit crops, the area survey also shows a decline in the national orchard of 4,000 ha, or 7% over the period 2000-20.

The fruit workshop at this Carrefour de l'Innovation agronomique, on the theme of Agricultural diversity and food diversity, without claiming to cover all these vast and multiform subjects, aimed to open up the debate on the specific features of the fruit sector, and the place given to diversity within it, thanks to a cross-section of viewpoints (in production, research and development) highlighting some of the sector's strengths, as well as some positive prospects.

Table 1: Key facts about fruit in France: strengths and weaknesses (authors' summary)

	PRODUCTION	CONSUMPTION
STRENGTHS	High-performance professional ecosystem Technical support in conjunction with the applied research system Official quality signs, brands and labels based on specifications Environmental advantages, range of varieties[1]	Image: naturalness, pleasure, well-being Nutritional supplements/recommendations, relayed by the specialist media Practical and suitable for snacking (some fruits) Overall confidence in the national product Increased spending on fruit
HANDICAPS	Production costs vs. challengers' costs Cost per hour & difficulty in recruiting labour Recurring climatic contingencies (e.g., frost in 2021) The weight and complexity of regulations Export embargoes, fraudulent 'francization' of imports (modification of the indication of origin to make it appear that the product originates in France) regularly denounced by professionals in the fruit sector in France.	Fruit quality sometimes irregular, brittleness and losses Sensitivity to the media environment [2] Price back as a buying priority? AB segment in difficulty (purchases down)

[1] The richness of the existing range of varieties is fuelled by a significant selection effort, which allows a renewal of the fresh produce offer (e.g., apples, apricots). However, the fruit diversity used in production and observed in distribution remains below the potential. In addition, for fruit that is mainly processed, varietal specialisation is sometimes very high (e.g., cherries, plums).

[2] A few problems with residues of plant protection products reported by the media, sometimes wrongly attributed to French producers (in the case of imports), can have an impact on the whole profession, through the fault of just a few.

2. A cross-section of French fruit production sectors:

2.1 Fruit: a product with multiple benefits, but subject to economic conditions

The benefits of a diversified diet with a high proportion of fruit (and vegetables) are fully recognised. Combined with physical activity and the fight against a sedentary lifestyle, a balanced diet rich in fruit and vegetables helps to improve the population's state of health and reduce the prevalence of chronic diseases (obesity, diabetes, in particular). Since 2001, the public authorities have strongly emphasised these benefits through a succession of national nutrition and health programmes (PNNS), of which PNNS4 represents the 2019-23 phase. These initiatives are rolled out at regional level, in particular through the regional health agencies (ARS), the training of nutritionists and dietician networks. In terms of knowledge, they are supported by public research (INRAE, INSERM) then analysed and relayed for fruit and vegetables by Aprifel, the fruit and vegetable research and information agency.

It's worth remembering that eating fruit plays an essential role in balancing the diet, thanks to its mineral composition (rich in potassium and calcium), fibre content, low calorie density and the presence of bioactive micronutrients (polyphenols, carotenoids, vitamins). Eating fruit helps eliminate sodium and promotes vascular, bone and visceral (liver, kidney, etc.) health; it stimulates transit and the intestinal microbiota, immunity, the fight against free radicals (antioxidant role), and the prevention of cardio-metabolic risks (Amiot-Carlin, 2019). However, it remains tricky to communicate only on the 'health' component of the fruit, as it carries many other positive attributes, which puts into perspective the interest in promoting it as a health food. European regulations on nutrition and health claims (Regulation No. 1924/2006) restrict communication based on positive lists (Annexes to Regulation No. 432/2012).

Consumers also have multiple expectations. As the sociologist E. Birlouez reported in 2019, quality attributes for many foods, including fruit, are attached to the product itself, as expressed by the '4S': safety, health, flavour, service (convenience, price), but they are also underpinned by production ethics (fair trade, environment, transparency, proximity, solidarity, etc.). Conversely, in the case of fruit, there is a high degree of sensitivity to negative media reports (e.g., on pesticide residues), although overall fruit retains a very high level of consumer confidence (CSA, 2023). Finally, fruit consumption is volatile and therefore sensitive to the economic climate, as recent studies by Credoc have shown. It has been observed, for example, that the section of the population most affected by food price inflation from 2021, and following the energy crisis in 2022, will make increasing trade-offs in terms of quantities and places of purchase, giving priority to price to the detriment of other attributes, resulting in a shift in range.

2.2 Promoting fruit production: e.g. the Vergers Ecoresponsables label

Sandrine Gaborieau, head of marketing and communications at the Association nationale Pommes Poires (ANPP), gave a presentation on the quality approach adopted by apple growers in France, under the Eco-friendly orchards label. While PFI became widespread at the end of the 90s in response to the need for more reasoned agriculture, and a need to reassure consumers about food safety issues, the ecoresponsible production approach born in the early 2000s is part of an ethic of producing healthy, tasty, quality fruit, obtained using methods that respect the environment and biodiversity. Since 2011, the Eco-friendly orchards' label has been part of this professional dynamic, marked by an openness to agro-ecology. By the end of 2022, this label will have become a strong marker in the apple (70% of volumes), peach-nectarine (80%), apricot (65%) and pear (43%) sectors. To date, nearly 2,000 orchardists have signed up to the specific production charter, recognised as equivalent to French level 2 environmental certification. In addition, the proportion of farms with individual High Environmental Value (HVE, level 3) certification has reached 60%. The French apple growers' quality charter is based on 10 modules, four of which are the subject of HVE certification (Figure 1), while three modules complete the scheme postharvest, at the fruit station: packaging, traceability and storage conditions. With the necessary

technical support, all the farms are regularly inspected by the (ANPP, and some of them are inspected every year by an independent external certification body.

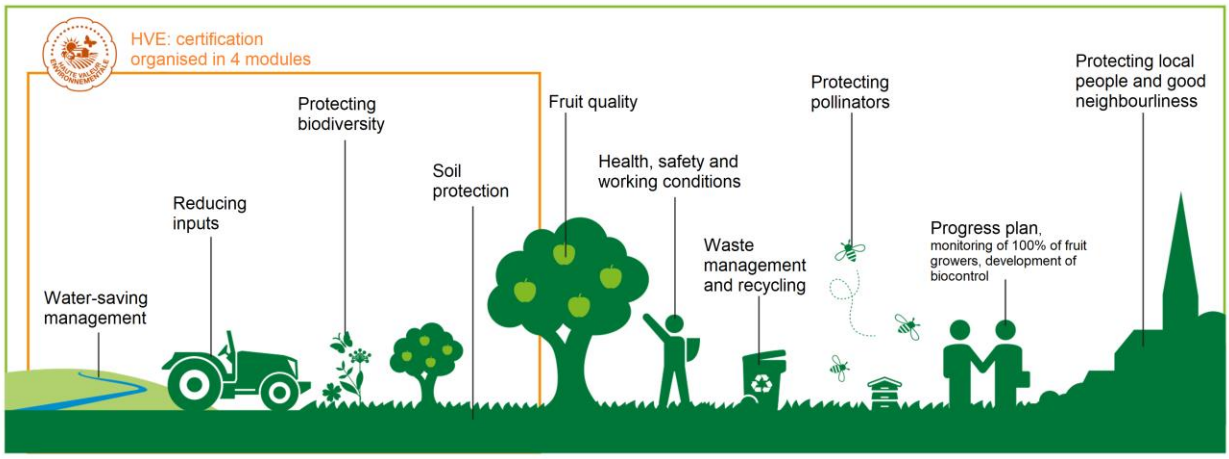

Figure 1: Modules of the Eco-friendly orchards French apple growing quality charter. (©, Association Nationale Pommes Poires)

The objective pursued by the approved profession for the Eco-friendly orchard charter and the logo that signs it is to place the fruit production process in a virtuous circle, where downstream confidence in the fruit production process stimulates its attractiveness, while the growing success of the approach is in turn increasing the visibility and awareness of the logo (known by 47% in 2021, 52% in 2022, Source Interfel/CSA/FranceAgriMer). The label also mentions the French origin in its graphics, which meets expectations for a 'local' product.

Various promotional activities are organised during the campaign, mainly using apples as a medium: "open orchards" operations at harvest time create a space for discovery and dialogue between approved producers and the general public, while various events (trade fairs, sporting events) provide an opportunity to highlight the approach and the labelled product. The press, social networks and in-store campaigns complete the picture. The effectiveness of the marketing around the Eco-friendly label can be measured by the responses of the sample of consumers who are aware of it: over 90% of them are reassured and confident in the recommended production methods, which equals or exceeds their confidence in other quality labels.

2.3. Fruit processing: a lever for making the most of varietal biodiversity

The topic of processing was presented by David Page and Justine Giroud-Argoud (INRAE, UMR SQPOV, Quality and Processes team), based on the example of the DiversiGO project led by the Groupe de recherche en agriculture biologique (Grab) (2019-2023), conducted in the South of France, on three fruit species with multiple uses: apples and pears (making compotes, extracting juice, and appertisation), and apricots (jams, fruit in syrup, nectars). It was pointed out that the fruit processing sector is dynamic in France, as indicated by public data from ADEPALE and FranceAgriMer. For example, compote production, in which apples dominate, is close to 400,000 tonnes, with 40% of compotes having no added sugar, and the industry is a net exporter.

The DiversiGO project, in its processing theme, was based on the observation that there was a lack of use of existing varietal diversity (for fruit farms located in Provence or the Durance Valley) in processing, with, for example, a predominance of the Golden Delicious variety for making apple compotes. Conversely, it is important to ensure that the finished products leaving the processing units are as regular as possible, despite the natural variability of the raw materials. This requires blending strategies based on an analysis of the fruit used.

The research team analysed a wide range of varieties for their suitability for processing: 29 varieties for apples, 9 for pears and 18 for apricots. For apricots in particular, varietal diversity is strongly expressed in the characteristics of the fresh plant matrix, with highly variable levels of carotenoids (hence the orange colour), soluble sugars (Brix level) and acidity, as well as a wide range of firmness, resistance to cooking and aromas. It is therefore possible, a priori, to segment the range of apricot-based processed products, in order to make the most of varietal diversity, bearing in mind that processing methods, which are themselves diverse, generate biochemical mechanisms that profoundly modify the initial varietal profile (Maillard reactions[3] , changes in flavour, etc.). It is therefore clear that the diversity of production results from an interaction between the variability of the fruit raw materials and that of the processes (Figure 2).

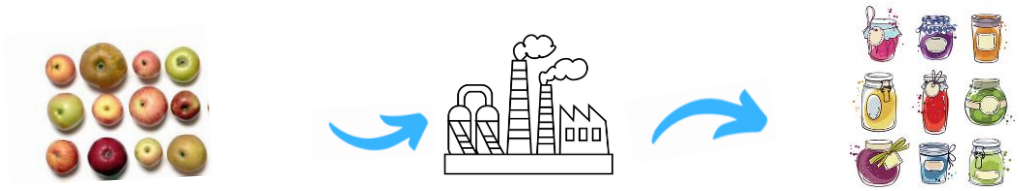

Figure 2: The interaction between varietal diversity and processes in processing units, as a source of variability in processed products (© Unité INRAE SQPOV)

A typology of regional processing plants (organic production, small-scale units) has been drawn up, particularly for apple juice extraction units, taking into account the use of resources (equipment, energy, water), raw material flows and material losses (pressed pulp). The final results of the DiversiGO project will be published shortly, as the SQPOV team's contribution is part of a broad regional partnership involving various regional organic partners (GRAB, Bio de Provence, for fruit). An analysis of the socio-economic component (interplay of players, value chain) is also expected, as is an analysis of the value-adding channels, potentially making the most of the advantages resulting from specific regional features.

2.4 Diversifying by introducing new crops to the farm: an example of fruit growing

The development of specialised, intensive agriculture in the 20th century was a response to the need for production performance, while at the same time the surface area of farms increased, in inverse proportion to the decrease in the number of farmers. The agronomic and environmental limits of intensive systems and monocultures are now well established. At the microeconomic level, moreover, agricultural specialisation entails risks, particularly in the face of market hazards and fluctuations. In their search for resilience, their vision of agricultural production, their response to societal expectations or their reconnection with consumers, a growing number of farmers have chosen to maintain or move towards diversified production systems, in particular by introducing new crops. This process can lead orchardists to introduce new fruit species, and/or to associate crop and livestock production on the farm (e.g., the presence of animals in orchards), and to combining crop speculations, for a better sharing of risks, and taking into account the necessary coherence in the use of production resources (working time, tools, etc.).

In the case of fruit crops, various avenues are being explored simultaneously in the southern regions of France, such as the redevelopment of almond production in Provence, and the cultivation of "new" species, such as persimmon, pomegranate and pistachio, which have been present historically and are a priori well adapted, but are insufficiently known technically and professionally structured (Figure 3). The theme of supporting fruit diversification was presented by Xavier Crété, an engineer at the SudExpé regional experimental station, using the example of the pomegranate sector.

3 Maillard reactions combine sugars and amino acids, and are responsible for browning and the production of various molecules with new aromatic properties.

Figure 3: Persimmon and pomegranate, fruits now produced as part of a diversification strategy, and supported in their production by the SudExpé experimentation station in Marsillargues (see text; © X. Crété, SudExpé)

As early as 2015, to meet the needs of players in this emerging sector, the station planted a pomegranate variety collection in Marsillargues, with funding from the Hérault department, then submitted projects and obtained funding (FranceAgriMer and FEADER) to support dedicated experimentation programmes. At the same time, a Federation of Southern Pomegranate Producers was set up (at the end of 2014), while SudExpé provided a large number of training courses for the players involved, with the participation of the Chambers of Agriculture and Civam organisations in the Occitanie region. The growth in pomegranate production (over 200ha in the region) then led the Federation to register a collective brand 'Grenades d'Occitanie' (registered in Sept. 2022), based on specifications, structuring the approach to promoting this 'super-fruit' (fresh and especially juice) and setting it apart from imported production. At the same time, economic interest groups (EIGs) were springing up around this fruit production in the PACA region (mainly provence). SudExpé's main role was to acquire regional references, particularly technical ones (management of climatic risks, irrigation, etc.). Growing pomegranates is not without its uncertainties and risks, and experimentation and training are essential to learning how to overcome and control growing difficulties (e.g., fruit shattering, new pests). The recent surge in volumes could lead to market overload, requiring strong interaction between players to promote products and stimulate demand.

3. Avenues of debate and prospects for innovation in the fruit sector

The fruit workshop presentations were followed by a lively debate. The discussions highlighted the major role played by stakeholders in the implementation of collective disciplines (Eco-friendly orchards' label), the regional coordination of fruit flows for processing, and the emerging partnerships that are helping to structure new sectors with the support of applied research projects. The technical benefits of a production concept based on the quest for biodiversity in cultivation have not been explicitly discussed, but the specifications (for production and distribution) strongly affirm this objective, the validity of which has been stressed (cf. § 1). On the other hand, local issues came up in the discussions, more or less explicitly (protection of people living near fruit-growing plots, "open orchard" days, new fruit species, promotion of regional assets and local products).

The dynamics of consumption underpinned the discussions: sustained consumer demand is a driving force behind the industry's performance, as it determines the balance between supply and demand, and therefore the level of remuneration paid to producers. It was noted that the level of fruit consumption is sensitive to structural factors: competition from sweet desserts (despite the recommendations of the PNNS), substitution by dairy products, often produced at low cost. But the fruit consumption is also very sensitive to the impact of the economic climate: the health crisis caused by Covid 19 and the confinement

of the population in 2020 boosted the volume of fruit purchased for home use, while since 2022, political events linked to ongoing conflicts have led to a rise in energy costs, which has an impact on costs at all levels of the fruit sector (inputs, production, storage, downstream logistics, etc.). The resulting inflation in retail prices is making consumers very cautious about buying fruit (split or limited baskets, price arbitrage at the expense of quality). Fruit processing remains an active segment, with both industrial facilities and on-farm workshops; it makes it possible to create value from sorting gaps, and to smooth out any production peaks, but it cannot be limited to being a safeguard for the quality of fresh fruit, because of the need to secure supplies to manufacturing units, but also because of quality specifications, calling for the creation of dedicated orchards. The consumption of processed fruit, which complements that of fresh fruit, could be stimulated by product innovation, and make the most of varietal diversity as part of a real industry dynamic (cf. § 2.3).

The importance of confidence-building attributes was also emphasised. Anything that helps reassure buyers about fruit is likely to have a favourable impact on the whole sector, whether it's consumers wanting to know more about tree-growing techniques, whether conventional or organic, understanding the challenges facing fruit producers in a context of global change, identifying labels, and being able to make purchasing decisions by overcoming a possible conflict between the qualities expected and the willingness to pay.

Future developments in the fruit sector should continue to be based on biodiversity (more diverse varieties and/or associated species), combined with technological innovation in orchards (redesigned, ecologised production systems with greater resilience, managed using precision farming practices to limit inputs), as this continues to condition upstream sustainability. The organic production segment is already very active in experimenting with innovative fruit-growing systems, whose produce is often sold through short distribution channels. Changes are also expected in consumption patterns (snacking, balance between fresh and processed fruit) and distribution (short distribution channels vs. self-service). All these changes will involve organisational dynamics (collective approaches, labels, regional projects, etc.), and will need to be implemented in line with future public policies.

Ethics

The authors declare that the experiments cited were carried out in compliance with the applicable national regulations.

Declaration on the availability of data and models

The data supporting the results presented in this article are available on request from the author of the article.

Declaration on Generative Artificial Intelligence and Artificial Intelligence Assisted Technologies in the Drafting Process.

The authors have used artificial intelligence-assisted technologies to translate from French to English.

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Authors' contributions

Text drafted by JLR and PP, and reviewed by the workshop participants.

Declaration of interest

The authors declare that they do not work for, advise, own shares in, or receive funds from any organisation that could benefit from this article, and declare no affiliation other than those listed at the beginning of the article.

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