What do we know about diet diversity? The nutrition-health viewpoint

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Dietary diversity is perceived positively, as a marker of diet quality. However, diversity is a rather complicated concept, which encompasses several dimensions, such as the number of items, their distribution, and their dissimilarity, at different levels of scale (from the food item to its category). Literature from developing countries has established that there is a minimum diversity necessary for nutritional security. Conversely, more recent data from developped countries have shown that dietary diversity may be associated with poor nutritional quality of the diet and overweight, which could be explained by consumer vulnerability to the plethora of unhealthy foods. The article will present ways to re-articulate diversity in diet quality and allow diversity to be beneficial to a balanced diet and health.

Keywords: Nutrition, diversity, variety, diets, nutritional quality, health

Introduction

"Eat a varied and balanced diet" is an adage... The importance of diversity is always mentioned in current discourse and has always been part of recommendations (U.S. Department of Agriculture and U.S. Department of Health and Human Services 1980). If diversity relates to food consumption, it is of course linked to the availability or supply of food and thus to the underlying food systems. Promoting diversity therefore means calling for a multiplicity of agricultural production and food processing methods. But is dietary diversity a determining, or simply an important, factor in diet quality? Is it always a positive characteristic? Why should it be, or under what conditions could it be?

Concept and dimensions of diet diversity

The concept of dietary diversity is a complicated one, much more so than might seem at first glance. Often the definition relates to the method: it is a question of counting (Ruel 2003). Counting food; but of course, what we are counting are different things. If I eat different variety of strawberry, such as *Charlottes*, *Gariguettes* and *Maras des bois*, does that "count" as three, or as one because then I eat strawberries in an undifferentiated way (i.e. I am eating "strawberries"), regardless of "dietary biodiversity"? (Hanley-Cook et al. 2021). If I eat strawberries, blueberries and apples, does that count as three, or two (red fruits and apples) or one (fruit)? From these examples, we can see that we are counting sets with a granulometry that can vary greatly. It is easy to see that this classification can take on variable characteristics and be linked to variable nutritional characteristics – we will come back to this later. So, even if we take the definition of diversity simply as a count, we can see that we come up against classification issues: issues of defining categories and issues of structuring categories. We also come up against questions of quantity: when is a consumption significant and therefore should it be counted? (Haines et al. 1999) In other words, does a single strawberry 'count' in terms of diversity?

We can also try to identify the different dimensions of the rather complex concept of diversity. There is the number of elements, of course, as we have just discussed; and with it the nature of the elements: often, when we count foods we talk about variety (total variety being the total number of foods consumed), whereas when we talk about diversity we more often refer to a number of food categories. We can only count the presence of a declared consumption, or index it in portions in relation to portion consumption references (Kant et al. 1991). To this absolute or portioned count, we can add the distribution of consumption, according to its degree of uniformity: in a given set (the diet, or a food category), are the elements (of the food categories, or of the foods in the category) consumed in similar proportions? Finally, to what extent are the elements consumed, which are different enough to be considered as different elements for counting purposes, actually different from the point of view of their nutrient attributes[1] ? Thus, some authors have proposed that, ultimately, number, distribution and dissimilarity form three dimensions of the concept of diversity (de Oliveira Otto et al. 2015; Hanley-Cook et al. 2022).

Minimum dietary diversity as nutrient security

This question of grouping into categories for counting purposes and dissimilarity in actual consumption takes us back to the positive characteristics of variety/diversity in nutritional terms. Indeed, the basic principle underlying the benefits of diversity is that we need to consume a certain number of different foods in order to achieve a balanced diet. In terms of basic nutrients, the principle seems to be based on the fact that a single food, or just a few foods, cannot provide all the nutrients we need in adequate quantities, so we need to eat a number of different foods so that, together, because they complement each other, they make up a balanced diet. Although some authors have shown that it is possible to optimise a diet of just 7 foods to ensure that nutrient requirements are met (Wilson et al. 2013) it is easy to imagine that in practice, subject to other constraints and objectives for making a diet, diversity can be favourable to the coverage of requirements.

As such, it is not surprising that, in developing countries, dietary variety and diversity have been associated with nutrient adequacy (Hatloy et al. 1998; Steyn et al. 2006; Habte and Krawinkel 2016). In this literature, diversity has been measured very variably (Ruel 2003) but the methods often have in common the ability to detect very monotonous diets that are unable to provide sufficiently varied contributors to the intake of indispensable nutrients (Martin-Prevel et al. 2015). In this sense, diversity makes it possible to account for nutritional insecurity, and diversity indices provide easily usable indices in the field in low-resource countries, even including minimum diversity thresholds that are effective for vulnerable population groups (Martin-Prevel et al. 2015).

However, there are a number of criticisms to be made about the significant methodological weaknesses of the nutritional adequacy indicators that most often used and give a crude reflection of the probability and seriousness of not meeting nutrient requirements. However, in developing countries, dietary variety and diversity have also been associated with direct assessment of nutritional status (Savy et al. 2005). In a review, we found associations between diversity and nutritional adequacy, but also sometimes (in 3 studies out of 7) between diversity and health criteria (Verger et al. 2021).

Finally, in developing countries, a minimum of diversity is necessary for dietary quality. We need to eat several foods, but above all several food categories (which are by construction dissimilar, and which often constitute identified nutritional vectors) to promote this complementarity throughout the diet in terms of nutrients.

A dark side to diversity?

In developped countries, the relationship between diversity and adequacy of intake of indispensable nutrients is also often found, and seems to be based on the same principle. However, the association with adequacy of intake of nutrients to be limited seems to be reversed. In the French population, we calculated the Haynes dietary diversity score, which counts the consumption of 45 sub-categories within 7 food categories in a hierarchical fashion. We showed that this general diversity score was strongly positively associated with the nutrient adequacy score (considered in terms of its ability to ensure intakes of indispensable nutrients up to the nutritional reference levels, according to the PANDiet system (Verger et al. 2012)). But the data revealed that this diversity was also negatively associated, albeit less strongly, with the nutritional moderation score (considered as its ability to avoid excessive intakes of nutrients, such as sugar, sodium or saturated fatty acids) - **Table** 1 (Bianchi et al. 2016).

Table 1. Relationship (regression coefficient β) between the dietary diversity score and the overall nutritional score (PANDiet Score) and the adequacy and moderation sub-scores in the total French population and by gender in the ENNS study. According to Bianchi et al. (Bianchi et al. 2016).

	DEPENDENT VARIABLES	**B (95% CONFIDENCE INTERVAL)**	***P***
TOTAL POPULATION			
	PANDiet score	*0.17 (0.12 ; 0.21)*	*<0.01*
	Subscore of adequacy	0.50 (0.43; 0.57)	*<0.01*
	Moderation subscore	-0.17 (-0.25; -0.08)	*<0.01*
MEN			
	PANDiet score	*0.16 (0.09 ; 0.22)*	*<0.01*
	Adequacy sub-score	0.49 (0.39 ; 0.59)	*<0.01*
	Moderation subscore	-0.18 (-0.30; -0.05)	*<0.01*
WOMEN			
	PANDiet score	*0.18 (0.11 ; 0.25)*	*<0.01*
	Adequacy sub-score	0.50 (0.43 ; 0.57)	*<0.01*
	Moderation subscore	-0.22 (-0.33; -0.11)	*<0.01*

The lower quality of the food consumed on diets that were highly diversified in terms of nutrients to be limited was explained in particular at the dietary level by a higher consumption of sweet products (Bianchi et al. 2016). This consumption was more than 50% higher in the quarter of the population with the most diversified diet (compared with the lowest quarter).

Furthermore, still in developped countries, and in this case in the US, de Oliveira Otto et al. reported that dietary diversity, as expressed by the dissimilarity dimension, was positively associated with increases in individual waist circumference over follow-up time (de Oliveira Otto et al. 2015). In our literature review, we found that dietary diversity was associated with at-risk body composition (i.e. being overweight or obese, or gaining weight) in 3 studies in developed countries (while 5 studies reported favourable associations, 5 mixed associations, and 7 no association). The situation was even strongerin middle-income countries, where the associations were most often unfavourable. The literature has also explored the relationship between diversity and long-term health. Here again, things seem to have moved on since the first studies. For example, in the United States, using an overall diversity score based on 5 food categories, Kant et al. reported an association between a lower diversity of consumption in the early 1970s

with a higher mortality rate (Kant et al. 1993). In our review, in developed countries, we found that there were more studies reporting mixed, no or unfavourable relationships than studies reporting favourable associations in terms of mortality and health criteria. Recent studies have shown that, in developed countries, metabolic health and morbidity are predicted by dietary quality scores but not by diversity scores (de Oliveira Otto et al. 2015; Fung et al. 2018). Variety of consumption within food categories that are not recommended is associated with excess body fat (Vadiveloo et al. 2013).

Thus, as summarised by de Oliveira et al., these results do not support the idea that 'eating everything in moderation' leads to better diet quality or better health (de Oliveira Otto et al. 2015; de Oliveira Otto et al. 2018). How can this phenomenon be explained? It has been argued that in a food context of developed countries, with commercial promotion mainly concerning foods of poor nutritional quality, the variety and diversity of diets could be a sign of a diet more inclined towards these foods (Vadiveloo et al. 2013). In short, it is thought that variety of supply encourages over-consumption in general, leading to dietary imbalance when energy-dense products of poor quality dominate the supply (Hetherington et al. 2006; Remick et al. 2009). This would explain our observation that in France, consumers with the most diversified diets also have the highest consumption of sweet products (Bianchi et al. 2016). It should be noted that this dietary diversity actually has different facets, since these individuals also have a higher consumption of fruit and vegetables (Bianchi et al. 2016). If this explanation is correct, which we believe it probably is, then it holds lessons about the importance of the quality of the food on offer, and the quality of the diversity on offer: offering a wide variety of fruit and vegetables, rather than the current wide variety of biscuits and crisps.

Not all diversity is good - linking diversity to nutritional quality.

It appears that dietary diversity is not directly and in isolation a good indicator of the quality of diets in western countries, and this is probably also true for some populations in developing countries undergoing rapid dietary transition (Popkin 2006). It must therefore be admitted that not all diversity is good. It is worth noting that this idea can be extended to areas other than dietary diversity, as it is found in the diversity of agricultural production, as illustrated in the article by Messean & Jeuffroy, entitled “How to (re)diversify agri-food systems: the case of field crops in Europe”.

A corollary of the proposition that "not all diversity is good" is that it is wrong to say that it is good to "eat everything", which therefore appears to be another nutritional new cliché. The conclusion should be that diversity should never be separated from the recommended dietary balance. It is therefore not nutritionally good to 'eat everything'; rather, we should eat what contributes to a diet that is generally recognised as being good for health.

There have been initiatives to combine the measurement of diversity and quality. For example, to estimate diversity at the level of food categories, we can propose counting food categories that are recommended categories (Haines et al. 1999) and to count in a portioned way as an attainment of a defined number of portions for each category (Kant et al. 1991). We can also propose counting diversity/variety within the recommended categories (Vadiveloo et al. 2013; Kruger et al. 2021). This is a much better measure of how well diets match dietary recommendations than of diet diversity in the general sense. Recent dietary indices therefore tend to integrate the dietary diversity component more closely with that of the quality of the food categories concerned, by measuring the contribution of diversity to achieving dietary health objectives. Of particular note is the proposal by Vadiveloo et al. for the development of a 'healthy diversity' score in the United States (US Healthy Food Diversity Index) (Vadiveloo et al. 2014). Such indices show strong associations with nutritional adequacy and health (Vadiveloo et al. 2015a; Vadiveloo et al. 2015b).

Playing on the right diversity? Example of the diversity of plant protein sources

We will now present an example illustrating the positive leverage effect that good diversity can have on the nutritional quality of diet. One important issue in the emerging nutritional transition is the proportion of animal and plant proteins in protein intake. Much more than a question of proteins in the strict sense (i.e. amino acids), it is a question of "protein package" (Mariotti and Huneau 2016; Mariotti 2019) – in other words, the nutrients and other substances associated with proteins in foods that are sources of plant and animal proteins. The issue of a more plant-based diet is accompanied by questions about changes in nutrient intake profiles, with the possibility that certain nutrients may be insufficiently consumed (such as iron, zinc, vitamin A, vitamin B12, etc.), while other nutrients may be consumed in more adequate quantities because they are more important (fibre, vitamin C, vitamin B9, etc.) or less important (saturated fatty acids) (Mariotti 2017; Neufingerl and Eilander 2021; Perraud et al. 2022). To explore this, we have simulated the replacement of animal protein foods by plant protein foods (Salome et al. 2020). However, we studied several plant-based substitution methods: either by the plant protein foods currently consumed, many of which (60%) are cereal-based foods, mainly refined (standard scenario); or by a plant protein mix in which we have increased the diversity by giving a greater share to other plant protein foods such as wholemeal starchy foods, pulses, nuts (or 'oilseeds', i.e. walnuts, almonds, peanuts, pistachios, etc.) - diversified scenario. As illustrated in **Figure 1**, starting from the current situation (with 33% animal protein in the protein consumed), the simulation has led to gradual scenarios that increase the level of plant protein in the diet to 78%.

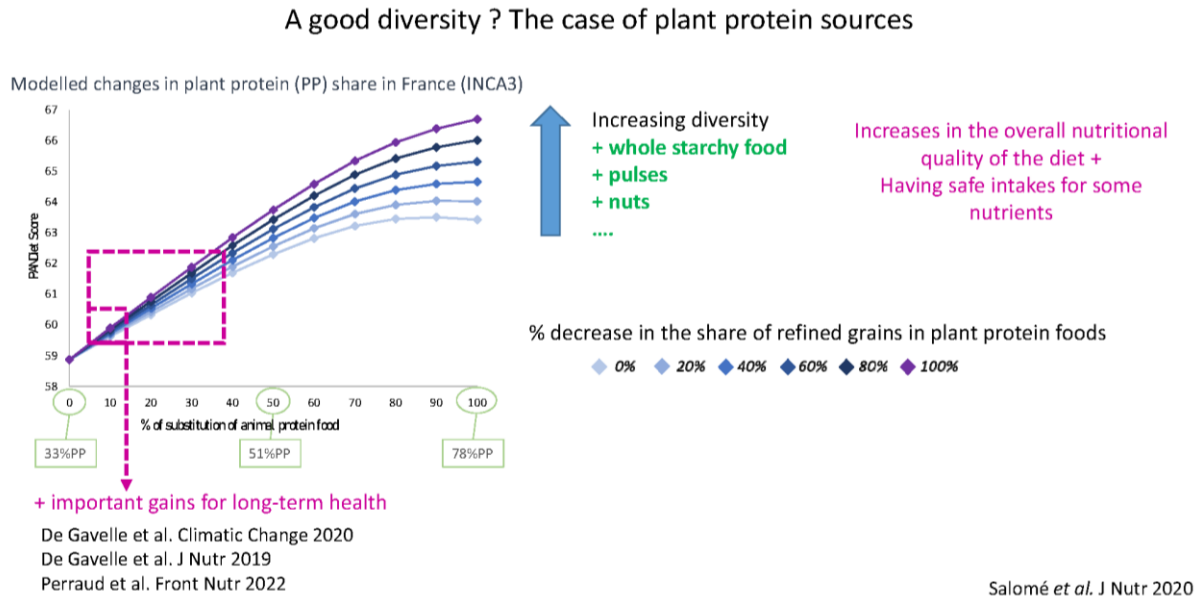

Figure 1: Simulation of a gradual substitution of animal protein foods by plant protein foods, from what is currently consumed in France (INCA3 survey, 2014-2015) [0% scenario] or according to a gradual increase in the diversity of the substitute plant protein mix, in favour of whole starchy foods, pulses and nuts, in particular, to the detriment of refined cereal-based foods [20-40-60-80-100% refined cereal reduction scenarios]. The graph on the left shows the evolution of an overall score for the nutrient quality of food (PANDiet score). According to Salomé *et al.* (Salome et al. 2020)

A more plant-based diet goes with an improvement in nutritional scores, but in the standard scenario the overall improvement in nutritional quality is encumbered by a reduction in the nutritional adequacy score, i.e. replacement by foods based mainly on refined cereal products leads to a decrease in the density of the diet in terms of indispensable nutrients. On the other hand, in highly diversified scenarios, this phenomenon does not occur because the other protein sources (wholemeal starch, pulses, nuts) ensure a richness in favourable nutrients while improving the profile of nutrients to be limited. In addition to this

diagnosis at nutrient level, it should be added that increased consumption of these food categories, which are recognised as favourable to long-term health, should logically be accompanied by reductions in morbidity and mortality, which can be characterised and have been reported to be effective for such slight changes in plant protein levels (de Gavelle et al. 2019; Fouillet et al. 2022; Perraud et al. 2022).

Research perspectives in nutrition

Research into diversity and quality has a great deal to offer. It appears that we need to study in detail the relationship between the nutritional profile of diets and their dynamics. Beyond the notion of diversity, which considers foods indiscriminately by simply counting them, we need to identify the leverage effects of certain foods, and certain sub-categories of foods. Certain foods, or even certain food categories, appear to be nutritionally inefficient, and so their consumption, while increasing diversity, does not increase quality - or even reduces it insofar as it competes with the consumption of foods or food categories that have a good nutritional density for the nutrients that tend to be limiting. This is what we describe by the term 'nutritional leverage' to describe foods or food categories that are efficient in defining healthy diets, particularly in a perspective of diet reorganisation or dietary transition (Dussiot et al. 2022).

In addition, we need to study which type of diversity dimension the health characteristics relate to, and in particular find out which type of diversity matters (number, distribution, dissimilarity, etc.). We have seen that the benefit of numbers seems to depend on the category that is counted or within which it is counted. What about distribution? Dissimilarity seems to be able to account for the ability of foods to complement each other, but is the degree of dissimilarity also an ambiguous dimension of quality? What does it depend on?

Finally, there has been relatively little research into the relationship with health effects from the point of view of the risk of excess intake of certain nutrients which, as we have seen, may be associated with certain aspects of diversity. We are not aware of any studies that have characterised the relationship between dietary diversity and the risk of excessive exposure to contaminants. However, it has been proposed (Wu et al. 2014; Ndemera et al. 2020) that varying the foods we eat results in variations in the quantity and nature of the contaminants consumed, thereby limiting the risk of excessive exposure to each of them. This principle is the basis of the French dietary advise concerning fish: "vary the species and places of supply" (Anses 2013). Finally, we should explore the determinants of health status that are not related to micronutrients, and one avenue would be the links between dietary diversity and the diversity of intestinal microbiota (Heiman and Greenway 2016).

Practical recommendations for beneficial diversity?

What practical recommendations can we draw from the overview we have just given? One of the central points seems to be the importance of measuring variety in categories that are favourable to health, so as to encourage consumption. Variety should also reduce the risk of excess intake of contaminants. On the other hand, no general nutritional benefits have been establishedas regard complementing foods that would give them a nutritional leverage effect. In fact, this effect depends more on the level of insufficient consumption of foods that are dense in nutrients that are currently insufficiently consumed. According to the same reasoning, dietary diversity should aim to increase the representation in diets of food categories that are consumed at low levels despite being nutrient-dense. This applies in large part to plant foods, as we have illustrated: legumes, wholegrain products, nuts, etc., but also certain animal products, such as offal.

Conclusions

The bottom line is that diversity must not be an isolated watchword that overrides all other aspects of diet, and nutrition in particular. If it is to make sense in terms of nutrition and health, diversity must be incorporated into the dietary recommendations, to accompany them. The recommendations of the French National Nutrition and Health Programme (PNNS) in terms of consumption guidelines (Anses 2016; Haut Conseil de la santé publique 2018) structure the dietary profile in terms of categories of food to be consumed, with a quantitative reference in terms of numbers of portions (e.g. 5 portions of fruit and vegetables per day, at least 2 portions of legumes per week, less than 500g of red meat per week) on which diversity can be based, and within which variety can be developed. In short, when it comes to nutrition, diversity and quality need to come together, which is what the adage "eat a varied and balanced diet" actually means, if we understand it correctly in a dialectical relationship. In a world of unbalanced food supply, people's **choices should focus on a diet that is both varied and nutritionally balanced, so that it is healthy and sustainable.**

Ethics

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

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

The authors have used artificial intelligence-assisted technologies to draw the first draft of the translation from French to English.

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Declaration of interest

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

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