Manuscript Details

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Abstract

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Keywords	food naturalness; consumers; integrative tool; labelling; food classification system; index
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The Food Naturalness Index (FNI): An integrative tool to measure the degree of food naturalness

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Abstract

Background: Consumers are increasingly demanding transparency in food labeling as they want more and better information about what they are eating and where their food comes from. This seems to be particularly the case for food naturalness. Several food indexes or metrics have been developed in the last decades to objectively measure various aspects of food, yet a comprehensive index that quantifies the naturalness of foods is still missing.

Scope and Approach: In the absence of clear rules to define and measure food naturalness, this article describes the development of the Food Naturalness Index (FNI), which aims to accurately measure the degree of food naturalness. The FNI simultaneously integrates and builds on insights from consumer research, legal and technical perspectives. A preliminary assessment of the index with consumers across a wide variety of products was conducted.

Key Findings and Conclusions: The FNI proposed herein is comprised of four component measures, namely farming practices, free from additives, free from unexpected ingredients, and degree of processing, which includes 10 relevant food naturalness attributes that can be consistently evaluated from information on the product label. The FNI scores were highly correlated with consumers' perceptions of food naturalness. The FNI has the potential to become a valuable tool in the process of reformulating existing products, developing new ones, and understanding, tracking, and communicating food naturalness attributes in the marketplace. Furthermore, the FNI may provide an objective basis for the use of the "natural" label on food products, which can ultimately lead to better-informed choices.

Keywords: food naturalness, integrative tool, consumers, labeling, food classification system, index

1. Introduction

The food industry is being increasingly scrutinized regarding the way products are marketed and labeled (Blok, Tempels, Pietersma, & Jansen, 2017, Sandin, 2017). It is fairly easy today to find packaged foods, such as salty snacks, microwavable dinners, or frozen pizza, in grocery stores positioned as "natural, all-natural, or 100% natural" (Berry, Burton, & Howlett, 2017, p. 1). Consumers consider this labeling an important attribute when making a food purchasing decision and billions of dollars are spent annually on these products (Chambers, Tran, & Chambers, 2019; Goodman, 2017). Several industry reports and consumer studies provide evidence that consumers seek out products that are labeled as "natural" (e.g., Consumer Reports, 2016; GNT, 2015; Liu, Hooker, Parasidis, & Simons, 2017).

A universal definition of naturalness that is accepted by producers, retailers, consumers, and governmental agencies does not exist. Foods labeled "natural" "are not made with uniform and certified production practices across farms and processors, and can contain ingredients that most consumers consider to be unnatural" (McFadden & Huffman, 2017, p. 226). This is in direct contrast to consumers' increased demand for transparency as they want more and better information about what they are eating and where their food comes from (Food Industry Executive, 2017a; Food Navigator, 2018). As a direct response, public and industry organizations have developed a number of initiatives, such as organic labels (e.g., Ellison, Duff, Wang, & White, 2016; Janssen & Hamm, 2012), clean labels (e.g., Aschemann-Witzel, Varela, & Peschel, 2019; Asioli et al., 2017), and sustainable labels (e.g., Grunert, Hieke, & Wills, 2014). Yet, there is no agreement as to what a label claiming "naturalness" represents or should include.

59 The objective of this article was to develop a comprehensive and standardized index
60 that simultaneously integrates and builds on insights regarding food naturalness from
61 consumer, legal, and technical perspectives.

62 The remainder of this article is structured as follows. First, a review of the concept of
63 food naturalness from consumer, legal, and technical perspectives is presented. Next, the
64 methodology used to develop the FNI is described. Then, a preliminary assessment of the
65 index with consumers across a wide variety of products was conducted. Finally, key
66 implications and conclusions are discussed.

67 2. A multidisciplinary perspective on food naturalness

68 The meaning of food naturalness may depend on the perspective from which it is
69 evaluated. The legal and technical perspectives may differ from the consumer's point of view,
70 for example. The conceptualization of food naturalness can be viewed from three different, yet
71 related perspectives, namely, consumer, legal, and technical.

72 *2.1. The consumer perspective*

73 Consumers' perceptions of food naturalness have received significant attention from
74 scholars. Specifically, Rozin and colleagues examined the meaning of food naturalness for
75 consumers (Rozin, 2005, 2006; Rozin et al., 2004, 2012) and identified a number of factors,
76 such as breeding technologies (e.g., GM technology) or processing technologies (e.g.,
77 transforming foods), that influence the perceived naturalness of food products. Román,
78 Sánchez-Siles, and Siegrist (2017) recently conducted a systematic review of consumers'
79 perceptions of food naturalness by examining 72 studies that collectively involved more than
80 85,000 consumers across 32 countries on four continents. Overall, this review found that
81 consumers place a high value on naturalness and that their perception of naturalness is
82 focused on the lack of negative attributes, such as additives, rather than on the presence of

83 positive attributes. This is consistent with the latest results from the Ipsos MORI Global
84 Advisor Survey (2018), which included 14,002 consumers across 28 countries.

85 The review by Román et al. (2017, p. 47) suggests that consumers distinguish three
86 separate yet related aspects of food naturalness: "(1) how the food is grown (relating to its
87 origin), (2) the way the food is produced and processed, and (3) the properties of the final
88 product (representing the result or outcome)." These three broad aspects are comprised of
89 fifteen attributes (Figure 1A). In particular, the origin of the food focuses on how food is
90 farmed and emphasizes organic farming and local production. The second category
91 distinguishes between the ingredients used and the production process. As for the ingredients,
92 consumers seem to place more importance on the absence of certain negative elements
93 (mainly additives, but also preservatives, artificial colors and flavors, chemicals, hormones,
94 pesticides, and genetically modified organisms) than on the presence of certain positive
95 elements (natural ingredients). The products should be as minimally processed as possible,
96 even resembling homemade foods. Using traditional food production methods is perceived as
97 preserving the food's natural state. The properties often attributed to natural foods are
98 healthiness, tastiness, freshness, and eco-friendliness (Román et al., 2017).

99 *2.2. The legal/regulatory perspective*

100 In the European Union, there are no general regulations for the use of the word
101 "natural" in the advertising or labeling of food products (except for some norms in the
102 "Flavouring Directive" and the "Additives Directive"). The Flavouring Directive represents a
103 good starting point regarding when and how to use the term "natural" in food labeling. More
104 specifically, the term "natural" must not be used when the origin of the flavor is, or has been,
105 obtained through chemical synthesis or isolated chemical processes. It can be considered
106 natural, however, if it has been processed for human consumption by one or more of the

107 traditional food preparation processes (e.g., freezing/deep freezing, pasteurization,
108 conditioning under protective atmosphere, concentration, and/or irradiation).

109 In the United States, the Food and Drug Administration (FDA) has provided a policy
110 statement regarding the term "natural" but has refused to regulate the use of the term (Farris,
111 2010). The FDA defines natural as "no artificial or synthetic ingredients added to a food that
112 would not normally be expected in the food item." The agency's reluctance to regulate the use
113 of the term "natural" has led to many private and class-action litigations over "natural" claims
114 on the labels of a variety of processed food products (Schlessinger & Endres, 2016). In
115 response, the FDA recently asked the public to provide information and comments on the use
116 of the term "natural" in the labeling of food products; more specifically, they asked "how the
117 agency should determine appropriate use of the term on food labels" (FDA, 2016). Unlike the
118 term "natural," the FDA has established legally-binding regulations for natural flavors. These
119 flavors are currently the fourth most common food ingredient listed on food labels in the US
120 (Goodman, 2017). Still, without a legally binding regulation of the term "natural," there has
121 been little opportunity to challenge the use of the term "natural flavors." Overall, there is no
122 formal definition of the word "natural" and therefore, no regulations pertaining to its use on
123 food labels across the world (Food Industry Executive, 2017b).

124 *2.3. The technical perspective*

125 Despite the difficulty of defining food naturalness from a technical perspective, there
126 are some food classification systems that have included "processing" and "product content
127 aspects" that are related to naturalness (Slimani et al., 2009; Monteiro et al., 2010; 2016,
128 Eicher-Miller, Fulgoni, & Keast, 2012; IFIC, 2010, Poti, Mendez, Ng, & Popkin, 2015), but
129 none of these classification schemes defines naturalness. Furthermore, these classification
130 systems focus on processing aspects and ignore other aspects of naturalness that are perceived
131 to be important by consumers (Román et al., 2017).

The most widely used framework is the NOVA food classification system developed by Monteiro et al. (2010; 2016), which is based on the extent and purpose of industrial processing. This system has been recently adopted by the Food and Agriculture Organization (FAO) (FAO, 2016), and it has been used in the national dietary guidelines of several countries (e.g., Ministry of Health of Brazil, 2014; Ministry of Health of Uruguay, 2016). This system focuses, however, only on a few aspects that are relevant for a comprehensive assessment of the naturalness of food products.

In short, despite differing viewpoints from food scientists and regulators regarding the definition of naturalness, consumers seem to have less of a problem with the term "natural." Findings from Román et al. (2017, p. 50) highlight the importance for consumers that natural foods are "free from preservatives, additives, and artificial ingredients". In what follows, we describe the development of an index that integrates all attributes proposed to be important for naturalness in order to provide a comprehensive scheme for assessing the naturalness of food products.

3. The Food Naturalness Index (FNI)

3.1. Identification and selection of the attributes

We used the food naturalness attributes reported by Román et al. (2017) in their review as a basis for the development of the FNI. Regulatory and technical insights were likewise followed in subsequent steps of the index development as explained below. The identification and selection of the index components were implemented through a two-step process depicted in Figure 1B.

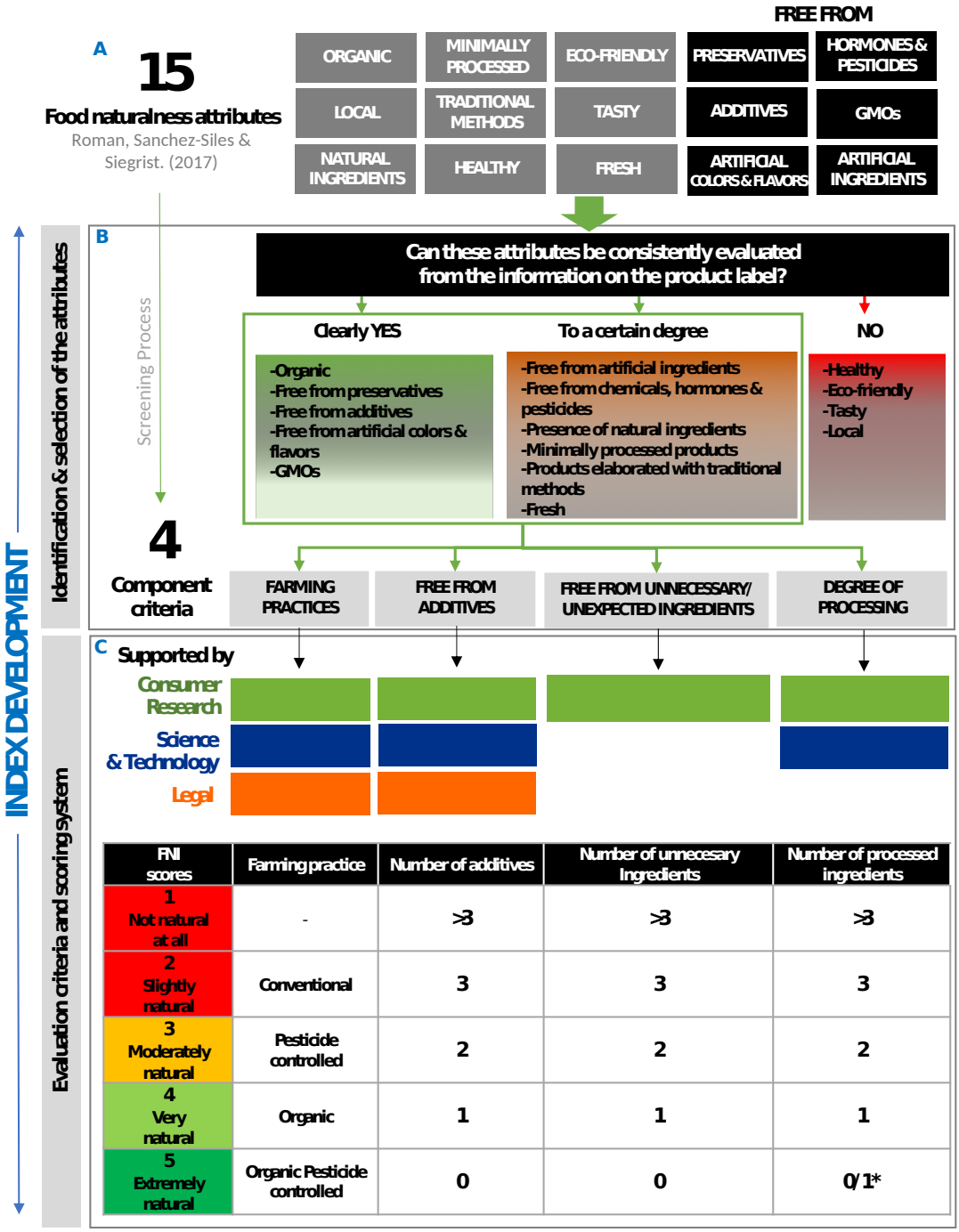

Figure 1. Conceptual framework for developing the index. From 15 food natural attributes (A), four component criteria (B), and the evaluation criteria and scoring system of the FNI (C). All components are supported with consumer research insights (green rectangles), three of them with science and technology insights (blue rectangles), and two with legal insights (orange rectangles).

*One processed ingredient only if: 1) declared gentle process on label and/or 2) stored chilled/frozen.

First, regarding the screening phase, the FNI is based on product information and claims available on the product label. As described earlier, consumers' perceptions of food

161 naturalness can be explained through 15 attributes (Román et al., 2017). As shown in Figure
162 1B, three of the attributes are perceived consequences of and not conditions for naturalness
163 (healthy, eco-friendly, tasty). While one attribute (local) cannot be determined without
164 ambiguity since it refers to food that "is sold close to where it was produced" (Witzling &
165 Shaw, 2019, p. 106); still, it is not at all clear what "close" actually means. Consequently,
166 these four attributes were not included in the index. GMOs are not currently present in foods
167 in Europe, and they need not be labeled in the US. Therefore, GMO status has also not been
168 included in the present version of the FNI.

169 The information about the remaining 10 attributes can be either clearly obtained from
170 the product label (organic, free from preservatives, additives, artificial colors and flavors) or
171 to some extent obtained from the product label (free from artificial ingredients, chemicals,
172 hormones and pesticides, presence of natural ingredients, minimally processed, traditional
173 methods, and fresh). In the latter case, there were some gaps in terms of the information that
174 can be obtained from the product label. Consequently, we used proxies to fill these gaps. This
175 was particularly the case for the attributes labelled "presence of natural ingredients" as will be
176 explained below.

177 Following Román et al. (2017), the 10 attributes were then classified[1] into more general
178 component categories, namely, (1) farming practice, (2) free from additives, (3) free from
179 unnecessary/unexpected ingredients, and (4) degree of processing (see Figure 1).

180

181 *3.2. Evaluation criteria and scoring system*

[1] The classification was independently performed by two of the authors, while a third one challenged their interpretations. Disagreements were debated among the researchers and usually involved minor refinements in the classification structure resulting in four component categories.

Building on Scarborough, Rayner, and Stockley's (2007), the methodology for ranking food items, the across-the-board-approach was used, and consequently, the FNI was developed and applied across all food categories. As depicted in Figure 1C, the evaluation criteria and scoring system for farming practices and free from additives components were built on consumer, legal, and technical insights. The free from unnecessary/unexpected ingredients component was solely based on extant findings from the consumer research literature, as legal and food science and technology evidence in this regard is lacking. Similarly, the degree of processing component draws on consumer and technical fields, as solid legal foundations are absent.

Each component category had a scoring range from 1 ("not natural at all") to 5 ("extremely natural"), except for the farming practice component, which varies from 2 ("slightly natural") to 5 ("extremely natural"). The overall index score is the average (arithmetic mean) of the four components and ranges from 1 to 5, where a value of 1 indicates that the food product is not natural at all, and a value of 5 indicates the highest possible level of naturalness.

Next, we describe the characteristics of each of the component categories of the FNI.

3.2.1. Farming practices

This component named "farming practice" is based on two natural attributes from Román et al. (2017), namely: 1) organic and 2) free from chemicals, hormones, and pesticides. These attributes were included in the farming practice component because depending on the type of farming, some standards and regulations restrict or limit the use of chemicals and pesticides. For example, this is the case for organic-certified food (McFadden & Hu□man, 2017; Padel, Röcklinsberg, & Schmid, 2009) or pesticide-controlled food, such as food targeted to infants and young children (Commission Directive 2006/125/CE; DeMaria & Drogue, 2017).

Organic is the only farming system whose management practices are codified by law in most countries (Seufert, Ramankutty, & Mayerhofer, 2017). Regarding baby food, although there are differences in the amount of pesticides residue across countries, most have stricter limits compared to products targeted at adults (DeMaria & Drogue, 2017). From the consumer point of view, the desire to avoid chemicals and pesticides is one of the primary reasons why consumers buy organic foods for adults and children (Hughner, McDonagh, Prothero, Shultz, & Stanton, 2007; Massey, O'Cass & Otahal, 2018) and organic baby food (Maguire, Owens, & Simon, 2006; Peterson & Li, 2011; Román & Sánchez-Siles, 2018).

Taking into account the types of farming practices and the current legislation in most developed countries (Willer & Lernoud, 2016; DeMaria & Drogue, 2017), there are four product types: 1) products from conventional agriculture, 2) pesticide-controlled (i.e., baby food grade), 3) organic products, and 4) organic pesticide-controlled products (i.e., organic baby food products and biodynamic certified products). Accordingly, the farming-practice component value of the FNI varies from 2 to 5, where higher values represent a more natural product based on the farming practice, taking into account consumers' perceptions regarding naturalness. Due to the fact that most food comes from conventional farming, we decided to start the scoring at 2 instead of 1, which would have meant "not natural at all."

Table 1 illustrates the differences among the four types of farming practices taking into account the level of pesticide use, the type of fertilizers, and the contaminant limits based on European legislations (Commission Directive 2006/125/EC; Council Regulation 834/2007/EC; Commission Regulation 889/2008/EC; Regulation 396/2005/EC).

Table 1

Differences in farming practice and scores on the FNI

FNI scores	Type	Description	Pesticide use	Fertilizers	Contaminant limits
2	**Conventional**	Food obtained from conventional agricultural and livestock farming practices	Pesticides used according to general regulations	Synthetic	Standard
3	**Pesticide controlled (i.e., baby food grade)**	Baby food obtained from conventional agricultural and livestock farming practices	Pesticides allowed, maximum residue 10 ppb or less. Control applied to comply with these levels.	Synthetic	Stricter* than conventional
4	**Organic**	Food obtained from organic agricultural and livestock farming practices	In general, no use of synthetic pesticides allowed. Possible presence of residues due to contamination. Complying to general regulation.	Natural	Standard
5	**Organic Pesticide controlled (i.e., organic baby food grade)**	Baby food obtained from organic agricultural and livestock farming practices	In general, no use of synthetic pesticides allowed. Maximum residue 10 ppb or less. Control applied to comply with these levels.	Natural organic fertilizers and pesticides	Stricter* than organic

*Stricter (adapted from DeMaria & Drogue, 2017). EU, Switzerland and South Africa: max 0.01 mg/kg. Canada: default limit of 0.1 mg/kg. Argentina, Australia, China, Korea, Mexico, Russia and USA: zero tolerance provisions or a very low maximum level

3.2.2. Free from additives

The definition of the attributes (free from additives, preservatives, and artificial colors) within the free from additives component was based on CODEX (CODEX, 2013, p. 22.) and the EU legislation (Regulation 1333/2008/EC) that defines additives. In Europe, additives are included in the International Numbering System for Food Additives (INS). Both preservatives and colors are considered additives and have what is called an E-number. EU legislation defines food additives as:

> "any substance not normally consumed as a food itself and not normally used as a characteristic ingredient of food, whether or not it has nutritive value, the intentional

addition of which to food for a technological purpose in the manufacture, processing, preparation, treatment, packaging, transport or storage of such food results, or may be reasonably expected to result, in it or its by-products becoming directly or indirectly a component of such foods" (Regulation 1333/2008/EC)

Additives can be used for various purposes, and the EU legislation defines 26 "technological purposes" that include colors, preservatives, antioxidants, artificial sweeteners, acidity regulators, raising agents, emulsifiers, and modified starches, among others. Research has shown that some consumers perceive the use of food additives in a rather negative way (Bearth, Cousin, & Siegrist, 2014; Altu & Elmaci 1995, Shim et al., 2011) as they are considered unnatural and even unhealthy. Moreover, the labeling of food additives with E-numbers instead of the chemical name decreases the perception of naturalness from the consumers' point of view (Evans, de Challemaison, & Cox, 2010; Pula, Parks, & Ross, 2014; Siegrist & Sütterlin, 2017); both chemical names and E-numbers decrease the perceived level of naturalness compared to a product free from additives. Accordingly, the free from additives component of the FNI includes the number of additives with an E-number or chemical name (i.e., E-300 or ascorbic acid). Nutritional additives such as vitamins and minerals that are added to food in order to "enrich" or "fortify" the food in question were excluded, so as to add or emphasize particular nutritional characteristics (Regulation 1925/2006/EC).

As shown in Figure 1C, the free from additives component value of the FNI varies from 1 to 5, where 1 implies that the product has more than three additives and 5 implies that it has no additives.

3.2.3. Free from unnecessary/unexpected ingredients

The free from unnecessary/unexpected ingredients component includes three attributes, namely, presence of natural ingredients, free from artificial ingredients, and free from artificial flavors. As natural and artificial attributes are antagonists, this component is focused

on the free from artificial ingredients attribute, which is directly related to the clean label trend. More specifically, the clean label phenomenon has driven the food industry to communicate that a certain, unexpected, ingredient is not present in the food product. An industry report by Ingredion (2014) recommends that food manufacturers keep the ingredient list short and simple, with ingredients that the consumer might find in their kitchen cupboards and feature minimally processed ingredients. Notably, a recent global consumer survey indicated that the percentage of consumers who avoided unnecessary ingredients grew from 35% in 2015 to 53% in 2016 (Euromonitor International, 2016). Similarly, in the latest "Health + Wellness" report (Hartman Group, 2017), most consumers say that they look for food and beverages that contain only ingredients they know and recognize. Overall, the clean label trend stems from consumers' perceived risk and skepticism toward certain ingredients (Asioli et al., 2017).

Unfortunately, there is no such thing as a standardized comprehensive list of ingredients that consumers do not expect in food products (excluding food additives). Still, building on several industry reports and empirical studies (Busken, 2013; Hartmann, Hieke, Taper, & Siegrist, 2018; Nielsen, 2017, Ingredion, 2014; Evans et al., 2010, Kerry, 2017), we developed a list of ingredients (excluding additives) that consumers:

(1) do not frequently use when making food at home and/or are not likely to expect to find in food product recipes. For example, artificial flavors are not considered additives and usually cannot be found in consumers' kitchen cupboards (e.g., Evans et al., 2010; Siegrist & Sütterlin, 2017).
(2) do not easily recognize (Ingredion, 2014; Hartman Group, 2017).
(3) find extremely difficult to understand (Aschemann-Witzel et al., 2019; Edwards, 2013).

A list of unnecessary/unexpected ingredients with some examples is shown in Table 2. Similar to the scoring system for the free from additives component, the free from unnecessary/unexpected ingredients component varies from 1 to 5, where 1 implies that the product has more than three unnecessary ingredients (shown in Figure 1C) and 5 implies that the product does not have any unnecessary ingredients.

Table 2

List of unnecessary/unexpected ingredients

Unnecessary/unexpected ingredients	Examples	Exclusions (Examples)	Source
Thickeners	Starch (corn, rice, tapioca, potato, wheat…) and maltodextrin, cellulose, etc.	Modified starch and other thickeners considered as additives	Evans et al. (2010), Kerry (2017), Ingredion (2014)
Non-commercial oils and fats	Palm oil, safflower oil, hydrogenated fats, partially hydrogenated oils, animal or vegetable fats where the origin is not mentioned (e.g., vegetable oils)	-	Ingredion (2014), Nielsen (2017), Kerry (2017), Hartmann et al. (2018)
Artificial flavors	Any flavor with the absence of the word natural* (i.e., strawberry flavor, vanilla flavor), accordingly Directive	Natural flavors are included in the processed ingredients group.	Ingredion (2014), Hartman Group (2017), Kerry (2017)
Glucose/fructose syrups	High-fructose corn syrup (HFCS), glucose syrup, fructose syrups, isoglucose (from corn or wheat)	-	Ingredion (2014), Hartman Group (2017), Nielsen (2017)
Added sugar (unexpected)	Added sugar in an infant food products	Added sugar in a dessert or a jam	Kerry (2017)
Added salt (unexpected)	Added salt in a sweet product	Added salt in a ready-to-eat meal	Hartman Group (2017), Kerry (2017)
Ingredients that are not expected to be in the product or recipe	Unexpected milk or milk-derived ingredients in products (lactose or cream powder in meat sausages, sweet whey powder in potato chips, skimmed-milk powder in a cereal bar, etc.) Other unexpected ingredients (flours in meat sausages, hydrolyzed soy in bolognese ravioli, etc.)	Products that clearly show in the food label that milk is present	

3.2.4. Degree of processing

Over the years, food processing has played a key role in extending the shelf life of food products, reducing food loss and waste, and improving nutrient availability (Van Boekel et al., 2010; Augustin et al., 2016). However, food processing also decreases freshness and some undesirable reactions may occur, such as loss of nutritional value and the formation of undesirable compounds (van Boekel et al., 2010).

In today's society, processed foods are perceived as less natural and may even be considered unhealthy (Szocs & Lefebvre, 2016) compared to unprocessed foods. Consumers generally have negative perceptions about food processing, usually related to technology mistrust, not fully understanding processing, and health-related issues (Ares et al., 2016; Augustin et al., 2016; Botelho, de Camargo, Dean, & Fiates, 2019; Cox & Evans, 2008; Van Boekel et al., 2010).

Numerous studies have shown that food processing and human manipulation decrease perceived naturalness (Rozin, 2006; Evans et al., 2010; Ingredion, 2014; Abouab & Gomez, 2015; Mouta, de Sá, Menezes, & Melo, 2016; Aschemann-Witzel & Grunert, 2017) and perceived healthiness (Ares et al., 2016). Consequently, there is an increased demand of minimally processed foods (Sillani & Nassivera, 2015), which is especially the case for fruit and vegetable products (Nassivera & Sillani, 2015).

The degree of processing component includes three attributes from Román et al. (2017), namely, 1) minimal processing, 2) traditional methods, and 3) freshness. These are interrelated attributes that have been linked to food naturalness in many studies (e.g., Hemmerling, Canavari, & Spiller, 2016; Honkanen & Olsen, 2009; Mooney & Walbourn, 2001; Roininen, Lähteenmäki, & Tuorila, 1999; Siegrist & Sütterlin, 2017). Food processing procedures like cooking, blanching, or freezing are familiar activities for consumers because they apply them in their own households. Thus, they can be considered traditional methods

(Butz & Tauscher, 2002). Modern food technology implies further development of traditional methods (e.g., high-temperature short time heating or vacuum cooking) as well as procedures that have been taken over from di□erent industry branches and adapted to food processing (e.g., high-pressure treatment).

Food processing and naturalness do not necessarily exclude each other. Optimization and control of the processing conditions (e.g., optimizing the time and temperature of heat treatment) can substantially reduce the undesirable effects of food processing while maintaining its benefits (Van Boekel et al., 2010). In this regard, previous research has defined minimal processing as techniques that not only preserve foods, but also retain to a greater extent, their nutritional quality and sensory characteristics through the reduction of heat as the main preservative action (Olsen, Menichelli, Sørheim, & Næs, 2012).

There is still no adequate framework for exclusively assessing food processing (Poti et al., 2015). Yet, several food classification systems based on the extent and purpose of industrial processing have been proposed (Slimani et al., 2009; Monteiro et al., 2010; 2016, Eicher-Miller Fulgoni, & Keast, 2012; IFIC, 2010, Poti et al., 2015). The most popular one is the NOVA system developed by Monteiro et al. (2010). This system classifies foods into different levels, ranging from “minimally processed” to “ultra-processed.” However, the system not only evaluates the type of processing, it also takes into account how the products are formulated (i.e., addition of additives, salt, fat, and sugar) (Botelho, Araújo, & Pineli, 2017; Popkin, 2017).

Given that the degree of processing is sometimes difficult to evaluate from the information displayed on the product label, a comprehensive list of highly processed ingredients (excluding unnecessary ingredients and additives already included in the index) was created. The development of this list was based on the examples used by Monteiro et al.

(2016) and Poti et al. (2015) (Table 3). Scoring values and examples in two categories of food products for the degree of processing criteria are shown in Table 4.

Table 3

List of processed ingredients

Processed ingredients	Examples	Exclusions (examples)	Classification based on NOVA/Poti *
Isolated ingredients	Natural starches, maltodextrin, casein, whey protein, isolated fiber (inulin, FOS, GOS, β-glucans, lignin, etc.)		Basic processed ingredient
Refined/processed fat	Plant oils (sunflower, olive, palm, canola, coconut, peanut, etc.), margarine, animal fats (butter, pork back lard, etc.)	Cream, less refined oils (virgin olive oil, cold pressed canola oil, etc.)	Basic processed ingredient
Any type of flavor	Natural or artificial flavors		Basic processed ingredient
Any refined sugar	Sugar, syrups (maple, agave, corn, rice, tapioca, cocoa, etc.), fructose/glucose syrups (HFCS, glucose, fructose, isoglucose, etc.)	Honey	Basic processed ingredient (sugar), ultra-processed (syrups)
Dehydrated/ concentrates and powdered ingredients	Dry milk, milk powder, cream powder, yogurt powder, fruit or vegetable powders, fruit concentrate	Dehydrated/dried/freeze dried fruit pieces	Processed for basic preservation
Refined cereals, flours, and pasta (Only in cereal-based products)	Cereal flour (wheat, rice, corn)	Claim of "wholegrain" in any flour, cereal, and pasta. Oat and barley because are usually whole grain.	Processed for basic preservation
Hydrolyzed cereals	Hydrolyzed infant cereals		Ultra-processed
Extruded cereals	Cereals snacks (puff corn, flakes)	Pasta is excluded	Ultra-processed

* Monteiro et al. (2016) and Poti et al. (2015).

Table 4

Scoring values and examples for the degree of processing criteria

FNI Scores	Description	Examples from fruit drinks and juices category*	Examples from the snack bars category
1 Not natural at all	Product with more than **3** processed ingredients	Milk-based fruit drink water, fruit juice (orange juice from concentrate, peach purée, carrot juice from concentrate), skimmed milk powder, sugar, stabilizer (pectin), flavor, acidulant (citric acid), vitamin A, vitamin C, vitamin E, sweetener (sucrose), colorant (E160a)	Sunflower seeds, sesame seeds, agave syrup, sweetened cranberries (cranberries, apple juice concentrate, sunflower oil), roasted oat kernels, rice syrup, cashew kernels, raisins (raisins, sunflower oil), flaxseed, chia seeds (salvia hispanica), cocoa bean bits, goji berries, physalis
2 Slightly natural	Product with **3** processed ingredients	Orange nectar, orange juice from concentrate, sugar, natural flavor	Peanuts, agave syrup, cane sugar, flaxseed, spice preparation (paprika, pepper, smoked salt, tomatoes, ginger, garlic, chili powder, cumin, oregano), salt
3 Moderately natural	Product with **2** processed ingredients	Orange nectar orange juice from concentrate, sugar	Peaches, apples, apple juice concentrate, citric acid, sulfur dioxide, flavoring.
4 Very natural	Product with 1 processed ingredient	Orange juice, orange juice from concentrate	Dates, cashew kernels, agave syrup, dried goji berries, cashew puree, dried physalis, freeze-dried raspberries
5 Extremely natural	Unprocessed or with **NO** processed ingredients or with 1 processed ingredient and with **one** of the following characteristics: • Declared gentle process on label (i.e., high-pressure processing (HPP)) • Stored chilled/frozen	Orange juice, chilled orange juice from concentrate or orange juice	Dried apples, dried dates, dried figs, raisins, cinnamon

* The underlined text corresponds to processed ingredients

3.3. A preliminary assessment of the FNI with consumers

An initial study was conducted to assess the extent to which the FNI index aligns with consumers' perceptions of food naturalness.

3.3.1. Method

Thirty food products from a Swiss online shop (Coop@home) were selected using the following criteria: a) no unprocessed foods (e.g., apples), b) foods from different categories

366 such as ready-to-eat meals, snacks and infant nutrition, and c) products within these categories
367 with low, medium, and high FNI. We chose the last criteria because several products in one
368 food category with a range of FNI from low to high to insure that in every category, not all
369 products were, from the perspective of the FNI, equal in naturalness. The objective was that
370 participants had to look closely at the product packaging and not just rank the foods according
371 to the food category (e.g., rate all baby foods as very natural and all ready-to-eat meals as
372 very unnatural.) The selected products with the respective FNI are listed in Supplementary
373 Table 1[2]).

374 A convenience sample of participants (N=85) was recruited through advertisements in
375 food stores and the Institute's mailing list. Participants' ages varied between 19 and 76 years
376 (M=38, SD=14), 55.2% were women, and 42.4% had a university education.

377 The products were presented in random order on a table. Study participants evaluated
378 the food products with packaging as they can be found in shops except perishable food
379 products (e.g., sausages), which were presented as photographs along with all information
380 found on the package. Participants were asked to take the products from this table and rank
381 them from "unnatural" to "natural" on a second table. Tied ranks were not allowed.
382 Participants did not receive an explanation about what natural is, and if they asked, they were
383 told that they should rely on their own perception of naturalness. After the ranking task,
384 participants completed a short questionnaire. After completion, they received their
385 compensation (CHF 20) and were debriefed. Participants needed from 20 to 45 minutes to
386 complete the entire task[3].

387

[2] Calculations of FNI scores are shown in Supplementary Table 2.
[3] For a similar procedure see Bucher, Muller, & Siegrist (2015) and Lazzarini, Zimmermann, Visschers, & Siegrist (2016).

3.3.2. Results

For each of the 30 food products, the mean rank of consumer evaluation and the FNI value were calculated (see Supplementary Table 1). The scatterplot in Supplementary Figure 1 shows the association between the FNI and the consumer perceptions of the 30 food products. Overall, the findings from this study reveal a highly significant and strong correlation between the FNI and consumers' perceptions of food naturalness (r=.89, $p < .001$, N = 30).

4. Discussion

Several food indexes or metrics have been developed in the last decades to objectively measure aspects related to diet (Kennedy, Ohls, Carlson, & Fleming, 1995; Kant, 1996), food sustainability (Gustafson et al., 2016; van Dooren, Douma, Aiking, & Vellinga, 2017), nutrition (Drewnowski, 2005; PAHO 2016, Julia & Hercberg 2017), and the degree to which food is processed (SIGA, 2018; Monteiro et al. 2010). To the best of our knowledge, an objective index that quantifies the naturalness of foods is not available. Given the increasing importance of and demand for naturalness in food products, this article proposes a comprehensive index to evaluate the degree of naturalness of food products.

The FNI was developed using the most current scientific, legal, and technical information available, as well as insights from the consumer perception literature.

The scheme used in the index was based on:

- the different farming practices that, according to legislation and standards, have differences in the use of pesticides, fertilizers and, therefore, influence the quantity of contaminants.
- the number of additives and unnecessary/unexpected ingredients.
- the number of processed ingredients, the use of minimal processing technologies, and the type of storage used (frozen, cold, or ambient storage).

412 The FNI reflects the complexity of the naturalness construct because no single
413 component forms the index. Consequently, doing well on only one component does not
414 ensure a high score. The FNI scores were highly correlated with consumers' perceptions of
415 food naturalness. The FNI has potential implications and applications for a variety of
416 stakeholders including policy makers, consumers, food manufacturers, and retailers as
417 discussed below.

418 *4.1. Practical implications and applications of the FNI*

419 For manufacturers, the FNI could potentially provide a good tool for developing new
420 foods and reformulating exiting ones toward more natural food products (e.g., by using as few
421 additives, processed ingredients, and unexpected ingredients as possible). In this endeavor,
422 companies may determine which areas need further improvement to advance food naturalness
423 in their products and categories. Companies may also benchmark their product portfolio
424 against their competitors based on FNI scores. For example, a brand may have a lower FNI, as
425 compared to its main competitor, as a result of having more products with additives,
426 unexpected ingredients (e.g., glucose/fructose syrup), and processed ingredients (e.g., fruit
427 concentrates, refined cereals and glucose/fructose syrup). A product portfolio analysis using
428 the FNI would help define naturalness goals for the future (e.g., in the next three years
429 additives will be reduced by 50%, glucose/fructose syrup will be eliminated, fruit
430 concentrates will be substituted by fruit puree, and refined cereals by whole grain cereals).

431 For policy makers, the FNI could help in the definition and establishment of the
432 rules/requirements to carry natural-related claims. This would address the increasing demand
433 of food legislators to provide objective product information regarding food naturalness that
434 would be useful in guiding consumers' purchase decisions. Food retailers and manufacturers
435 could use the FNI for labeling and communicating the naturalness of food products in an
436 objective and easy-to-understand way. We believe that the FNI could have a significant

impact in the food environment if a multi-stakeholder partnership (which includes industry and regulators) were established.

In terms of labeling and communication, the FNI could be used in several ways. Similar to the Nutri-Score, a five-color front-of-pack (FOP) nutrition label that aims to orient consumers towards healthier food choices (Julia & Hercberg, 2017), a naturalness logo could use five colors from "not natural at all" (red) to "extremely natural" (light green). This logo could facilitate consumers' decision making during food shopping, as they would not have to invest a great deal of time in processing information. Information search costs and misinformation about "natural" foods would be significantly reduced, which seems to be particularly relevant as consumers are increasingly demanding simplified information on food packaging (Grunert & Wills, 2007; McFadden & Huffman, 2017). The use of FOP nutrition labeling along with the FNI would enable consumers to better differentiate between nutritional/health and the natural properties of food products. This is very important because extant research has found that consumers perceive natural foods as healthier (e.g., Román et al., 2017), although this is not necessarily the case. Therefore, the FNI will hopefully result in a more transparent purchase evaluation process by consumers.

Similar to the recently implemented ScanUp[4] in France, which is focused on the degree of processing, FNI scores could be easily available to consumers through a phone app to be developed in the future. In addition, the FNI could be used as a comparison tool in e-commerce. Consumers could easily obtain information about a product's degree of naturalness while shopping.

[4] More information available in: https://www.foodnavigator.com/Article/2018/12/04/ScanUp-The-app-that-tells-consumers-if-food-is-ultra-processed-and-helps-manufacturers-reformulate.

458 In summary, we believe that the use of the FNI can result in a more transparent process,
459 where consumers' likelihood of being deceived is minimized. The use of the FNI can
460 therefore improve transparency in the marketplace. This is particularly relevant in the light of
461 evidence from several studies and industry reports that suggest there is a lack of trust in the
462 food industry (e.g., Food Industry Executive, 2017a; Hartmann et al., 2018).

463 *4.2. Limitations and future research*

464 The FNI was developed using most of the attributes proposed by Román et al. (2017).
465 Future updates of the FNI may include information about sustainability issues and local
466 production when they are defined in a consistent and straightforward way across nations and
467 regions. In addition, even though the FNI includes a comprehensive list of
468 unnecessary/unexpected ingredients based on industry reports and empirical studies, future
469 research is needed to examine which ingredients are clearly expected by consumers and which
470 are not.

471 The FNI was developed in the European context building on current European food
472 regulations. Future studies may apply the index in other continents and nations. In some cases,
473 adaptations would be needed. For example, if implemented in the US, GMO status would
474 need to be included.

475 In the current study, the association between the FNI and consumers' perceptions of
476 naturalness was initially assessed using a wide variety of product categories. Several of the
477 products selected for the experiment were visibly different in terms of naturalness (e.g.,
478 organic pear puree for infants vs. chocolate cookies). More efforts are needed to further
479 validate the FNI by examining the relationship between the FNI score and consumers'
480 perceptions within the same product category (e.g., sugary snacks). The experiment was
481 conducted in Switzerland; studies with consumers from other countries are needed. Similarly,

scholars may use the FNI as a basis to develop a multi-item scale to measure food naturalness through consumer surveys.

Interestingly, future research may compare the relationship between food naturalness (FNI) and other food aspects, such as degree of processing (NOVA), nutritional/health properties (e.g., Nutri-score, traffic light labels), or sustainability measurements (e.g., Life Cycle Assessment). The FNI could be also used to compare naturalness across food categories (e.g., snacks vs. fruit-based products), brands, or even countries (e.g., FNI value of snack bars sold in one country compared to other countries).

In conclusion, this article proposes a comprehensive and standardized index that significantly builds on insights of food naturalness from consumer research, but also from legal and technical perspectives. This index could help eliminate the misuse of the "natural" label and could lead to better-informed choices, reduce suboptimal consumption, and decrease the legal risk of marketing food products. Therefore, we believe that the Food Natural Index has the potential to become a valuable tool in the process of reformulating existing products, developing new ones, and understanding, tracking, and communicating food naturalness attributes in the marketplace. Ultimately, this could result in a higher level of trust in the industry.

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Supplementary Table 1

Products used in the study with the FNI value and mean ranking of naturalness by consumers

Description	Mean (consumers' perceptions)	Std. Deviation	Food Natural Index (FNI) values
Extruded sour cream and onion chips	4.19	4.21	1.5
Dried quick pasta with cheese	4.78	4.10	1.5
Chocolate cookies with vanilla cream filling	4.78	4.09	1.3
Canned ravioli Bolognese	5.61	5.03	1.5
Cervelat sausages	8.01	6.19	2.5
Raspberry yoghurt for infants	8.68	5.04	2.3
Organic grilling sausages	11.49	7.18	3.0
Organic petit beurre chocolate cookies	11.81	6.46	2.0
Pasta with Bolognese sauce for infants	11.89	5.86	3.3
Cereals with chamomile for infants	12.98	6.82	3.5
Apple compote drinking pouch	13.75	5.79	3.3
Strawberry jam	13.93	5.77	3.5
Organic petit beurre cookies	13.96	6.26	2.3
Biscuit porridge for infants	14.15	6.74	2.0
Crunchy cereal bar	14.61	6.19	2.8
Organic spaghetti Bolognese baby food jar for infants aged 8 months or older	15.00	5.79	3.5
Insect Burger	16.84	7.38	3.0

Organic spaghetti Bolognese baby food jar for infants aged 12 months or older	17.04	6.03	4.5
Organic strawberry jam	17.84	5.70	4.0
Apple compote	18.69	6.02	3.5
Apple-banana puree for infants	18.74	5.65	4.3
Organic fruit bar apple-banana	18.98	6.07	4.0
Steamed whole-grain rice	19.25	7.04	3.8
Organic extruded crunchy millet snack for infants	20.68	8.14	4.8
Organic grain porridge for infants	21.64	5.85	5.0
Organic pear puree for infants	23.53	6.00	5.0
Organic apple-banana compote	23.62	5.35	4.8
Organic apple-kale smoothie	23.93	4.93	4.8
Organic four-grain cakes with sesame	25.58	4.32	4.8
Organic whole-grain rolled oats	29.02	3.43	4.5

Supplementary Table 2. Food Naturalness Index (FNI) calculation in the 30 products of study.

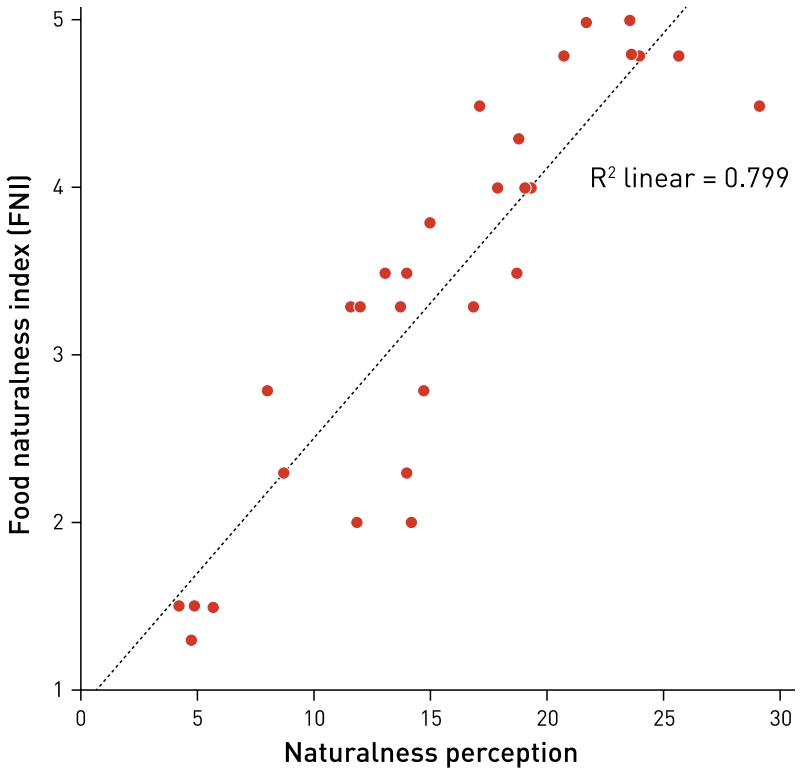
PRODUCT NAME	LIST OF INGREDIENTS	FARMING PRACTICE	ADDITIVES	UNEXPECTED INGREDIENTS	PROCESSED INGREDIENTS	FARMING PRACTICE SCORE	FREE FROM ADDITIVES SCORE	FREE FROM UNEXPECTED INGREDIENTS SCORE	DEGREE OF PROCESSING SCORE	FNI
Extruded sour cream and onion chips	Potato puree powder, vegetable oil, vegetable fat, rice flour, wheat starch, emulsifier E471, maltodextrin, hardened vegetable fat, onion powder, sour cream powder, dextrose, aroma, sugar, sweet whey powder, lactose, milk protein, potato starch, acidifier: citric acid, milk, modified starch.	Conventional	Emulsifier E471, acidifier: citric acid, modified starch.	Vegetable oil, vegetable fat, wheat starch, maltodextrin, dextrose, aroma, sugar, sweet whey powder, lactose, milk protein, potato starch	Potato puree powder, vegetable oil, vegetable fat, wheat starch, maltodextrin, onion powder, sour cream powder, dextrose, aroma, sugar, sweet whey powder, lactose, milk protein, potato starch	2	2	1	1	1,5
Dried quick pasta and cheese	60% pasta (hard-wheat semolina, wheat flour, whole egg (“barn eggs”)), 13% processed cheese (with smelting salts: sodium phosphates), modified potato starch, vegetable fat and oil (palm, sunflower), maltodextrin from corn starch, iodized cooking salt, glucose, lactose, whey powder, roasted onion, yeast extract, flavors (with milk), milk protein, acidifier (citric acid). May contain soya, celery, mustard.	Conventional	Sodium phosphate, acidifier (citric acid), modified potato starch	Palm oil, maltodextrin, glucose, lactose, whey powder, flavor, milk protein	Pasta refined, processed cheese, palm oil, sunflower oil, maltodextrin, glucose, lactose, whey powder, yeast extract, flavors, milk protein	2	2	1	1	1,5
Chocolate cookies with vanilla cream filling	Wheat flour, sugar, palm oil, low-fat cocoa powder 4.6%, wheat starch, glucose-fructose syrup, raising agent (potassium hydrogen carbonate, sodium bicarbonate, ammonium hydrogen carbonate), cooking salt, palm kernel oil, emulsifiers (soya lecithin, sunflower lecithin), flavor (vanilla).	Conventional	Potassium hydrogen carbonate, Sodium bicarbonate, ammonium hydrogen carbonate, soy lecithin, sunflower lecithin	Palm oil, wheat starch, glucose-fructose syrup, cooking salt, flavor	Wheat flour (refined), sugar, palm oil, low-fat cocoa powder, wheat starch, glucose-fructose syrup, flavor	2	1	1	1	1,3

PRODUCT NAME	LIST OF INGREDIENTS	FARMING PRACTICE	ADDITIVES	UNEXPECTED INGREDIENTS	PROCESSED INGREDIENTS	FARMING PRACTICE SCORE	FREE FROM ADDITIVES SCORE	FREE FROM UNEXPECTED INGREDIENTS SCORE	DEGREE OF PROCESSING SCORE	FNI
Canned ravioli Bolognese	Water, beef 10.9%, durum wheat semolina, tomato puree concentrate 6.5%, red wine, carrot, pasteurized eggs 1.4%, breadcrumbs, seasoning preparation (cooking salt, spices, spices, flavor enhancer (E621), sugar, lactose, vegetable juice concentrate powder, spice extracts (with celery), onion extract, flavors, coloring (E150c)), dried seasoning (with hydrolyzed soy and wheat protein), sunflower oil, herbs and spices, bacon, potato starch, table salt (1.3%), modified waxy maize starch, spice extracts, flavor enhancer (E621).	Conventional	Flavor enhancer (E621), coloring (E150c), modified waxy maize starch	Sugar, lactose, vegetable juice concentrate powder, flavors, hydrolyzed soy, wheat protein, potato starch	Tomato puree concentrate, pasteurized eggs, sugar, lactose, vegetable juice concentrate powder, onion extract, hydrolyzed soy, wheat protein, sunflower oil, potato starch, spice extract	2	2	1	1	1,5
Cervelat sausages	Pig 28% (Switzerland), ice, beef 22% (Switzerland), bacon (Switzerland), rind, salt cured with nitrite (salt, preservative (E250)), iodized salt, stabilizers (E450, E452), antioxidant (E300, E301), sunflower oil, spices, acidifier (E262).	Conventional	Preservative (E250), stabilizers (E450, E452), antioxidant (E300, E301), acidifier (E262)	salt cured with nitrite	Sunflower oil.	2	1	4	4	2,8
Raspberry yoghurt for infants	Reconstituted fermented milk (France) (68%), cream (milk) (11%), raspberry (10%), sugar, modified corn starch, water, natural flavor, carrot juice*, locust bean flour, acidifier (citric acid), emulsifiers (mono- and diglycerides of rape), antioxidant (L-ascorbic acid). Carrot juice provides the red color. Contains: milk, lactose. Without Gluten.	Baby Food	Modified corn starch, acidifier (citric acid), emulsifiers (mono- and diglycerides of rape), antioxidant (L-ascorbic acid)	Carrot juice, locust bean flour	Reconstituted fermented milk, sugar, natural flavor	3	1	3	2	2,3
Organic grilling sausages	Pig 56%, bacon, ice, milk 8%, veal 5%, iodized salt, seasoning, acidifiers (E331), glucose syrup, sugar. Envelope: pig casing.	Organic	Acidifiers (E331)	Milk, glucose syrup, sugar	Glucose syrup, sugar	4	4	2	3	3,3

PRODUCT NAME	LIST OF INGREDIENTS	FARMING PRACTICE	ADDITIVES	UNEXPECTED INGREDIENTS	PROCESSED INGREDIENTS	FARMING PRACTICE SCORE	FREE FROM ADDITIVES SCORE	FREE FROM UNEXPECTED INGREDIENTS SCORE	DEGREE OF PROCESSING SCORE	FNI
Organic petit beurre chocolate cookies	Milk chocolate 44% (raw cane sugar, cocoa butter, whole milk powder, cocoa mass, skimmed milk powder, vanilla beans), wheat flour (semi-white, wholegrain 8%), raw cane sugar, butter 5%) wheat starch, skimmed milk powder, wheat semolina, whole egg, table salt, rising agent (E503, E500), vanilla extract, glucose syrup, emulsifier (E322 from soy).	Organic	Raising agent (E503, E500), emulsifier (E322 from soy)	Wheat starch, table salt, glucose syrup, vanilla extract	Sugar, cocoa butter, whole milk protein, cocoa mass, skimmed milk powder, wheat starch, glucose syrup, vanilla extract	4	2	1	1	2,0
Pasta with Bolognese sauce for infants	Vegetables (tomato puree 40%, carrots, onions, parsnips, corn, red peppers), water, cooked pasta 11% (water, hard wheat semolina, egg white), beef 8%, starch, rapeseed oil, extra virgin olive oil, cooking salt, sunflower oil, natural flavor, garlic, basil, oregano.	Baby Food	-	Starch	Starch, rapeseed oil, sunflower oil, natural flavor.	3	5	4	1	3,3
Cereals with chamomile for infants	Rice semolina 70% (partly converted into starch sugar), maltodextrin, chamomile extract 1%, vitamins (C, E, niacin, B1, A, B6, folic acid, D), minerals (iron (IVI) fumarate, zinc sulphate, potassium iodide), lactic acid bacteria culture (B. lactis), natural flavors. May contain milk. Gluten free	Baby Food	-	Maltodextrin	Maltodextrin, chamomile extract, natural flavors.	3	5	4	2	3,5
Apple compote drinking pouch	Apples 75.3%, mirabelles 20%, sugar, natural flavor, antioxidant: ascorbic acid, acidifier: citric acid.	Conventional	Antioxidant: ascorbic acid, acidifier: citric acid.		Sugar, natural flavor	2	3	5	3	3,3
Strawberry jam	Fruits (strawberries 40%, red currants 10%), sugar, gelling agent (pectin), acidifier (citric acid).	Conventional	Gelling agent (pectin), acidifier (citric acid).	-	Sugar	2	3	5	4	3,5

PRODUCT NAME	LIST OF INGREDIENTS	FARMING PRACTICE	ADDITIVES	UNEXPECTED INGREDIENTS	PROCESSED INGREDIENTS	FARMING PRACTICE SCORE	FREE FROM ADDITIVES SCORE	FREE FROM UNEXPECTED INGREDIENTS SCORE	DEGREE OF PROCESSING SCORE	FNI
Organic petit beurre cookies	Wheat flour (semi-white, wholemeal flour 15%), raw cane sugar, butter 10%, wheat starch, skimmed milk powder, whole egg, table salt, raising agent (E503, E500), vanilla extract. All agricultural ingredients come from organic production	Organic	Raising agent (E503, E500)	Wheat starch, skimmed milk powder, table salt vanilla extract	Raw cane sugar, butter, wheat starch, skimmed milk powder, vanilla extract	4	3	1	1	2.3
Biscuit porridge for infants	Demineralized whey powder (26%), cereal flour (wheat (20.1%), oats, rice, millet, barley, maize, rye) low-fat milk (17.3%), ground butter biscuit 16% (wheat flour, butter, whey protein, raising agents (ammonium carbonates), citric acid), vegetable fats (palm oil, rapeseed oil), ground rusks 7% (wheat flour, palm oil, yeast), minerals (calcium carbonate, iron diphosphate, potassium iodide), vanilla, maltodextrin, vitamins (C, E, A, D, Biotin, B1, B6).	Baby Food	Ammonium carbonate, citric acid	Demineralized whey powder, low-fat milk, palm oil, vanilla, maltodextrin,	Demineralized whey powder, low-fat milk, butter, whey protein, palm oil, rapeseed oil, vanilla, maltodextrin	3	3	1	1	2,0
Crunchy cereal bar	Cereals 34% (oats, wheat, rice), sweeteners (E965), soy seeds, hazelnuts, skimmed milk powder, flavor	Conventional	Sweetener (E965)	Skimmed milk powder, flavor	Refined cereals, skimmed milk powder, flavor	2	4	3	2	2,8
Organic spaghetti Bolognese baby food jar for infants aged 8 months or older	Tomatoes 34%, water, spaghetti cooked 19% (pasta from hard wheat semolina), carrots, beef 5%, celery, rapeseed oil 2,2%, rice starch flour wheat, onions, iodized salt, spices (oregano).	Organic Baby Food	-	Rice starch, salt	Rapeseed oil, rice starch, flour refined	5	5	3	2	3,8
Insect burger	Flour worm (Tenebrio Molitor) 31%, rice, vegetables (carrot, celery, leek), eggs (free range eggs), lemon fiber, sunflower oil, onions, wheat flour, salt, paprika, oregano, garlic, pepper, chili.	Conventional	-	Lemon fiber, wheat flour	Lemon fiber, sunflower oil	2	5	3	3	3,3
Organic spaghetti Bolognese baby food jar for infants aged 12 months or older	Vegetables 48.4 % (tomato* 30.4 %, carrot* 16 %, leek*), water, wheat spaghetti** 9.9 %, beef* 8 %, rice semolina**. *from biodynamic agriculture **from organic farming	Organic Baby Food	-	Rice semolina	Refined wheat spaghetti	5	5	4	4	4,5
Organic strawberry jam	Strawberries, sugar, lemon juice concentrate, gelling agent (E440).	Organic	Gelling agent (E440)	-	Sugar, lemon juice concentrate	4	4	5	3	4,0

PRODUCT NAME	LIST OF INGREDIENTS	FARMING PRACTICE	ADDITIVES	UNEXPECTED INGREDIENTS	PROCESSED INGREDIENTS	FARMING PRACTICE SCORE	FREE FROM ADDITIVES SCORE	FREE FROM UNEXPECTED INGREDIENTS SCORE	DEGREE OF PROCESSING SCORE	FNI
Apple compote	Apple 92%, sugar, ascorbic acid	Conventional	Ascorbic acid	Sugar	Sugar	2	4	4	4	3,5
Apple-banana puree for infants	Apples 83.8%, banana pulp 16%, lemon juice concentrate, vitamin C. Gluten-free	Baby Food	-	-	Lemon juice concentrate	3	5	5	4	4,3
Organic fruit bar apple-banana	Apple juice concentrate* 44 %, bananas dried* 41 %, rice flour*, wholegrain spelt wafer*5 % (wholegrain spelt flour*, potato starch*). *from organic farming.	Organic Baby Food	-	Potato starch	Apple juice concentrate, rice flour, potato starch	5	5	4	2	4,0
Steamed whole-grain rice	Whole parboiled rice (98%), sunflower oil, natural flavor (contains celery), salt.	Conventional	-	-	Sunflower oil	2	5	5	4	4,0
Organic extruded crunchy millet snack for infants	Extruded millet* (100%). *from organic farming	Organic Baby Food	-	-	Extruded millet	5	5	5	4	4,8
Organic grain porridge for infants	Wholegrain rice flour* 70 %, demeter corn flour** 20 %, wholegrain millet flour* 10 % thiamin (required by EU law) *from organic agriculture **from biodynamic agriculture Ecological.	Organic Baby Food	-	-	-	5	5	5	5	5,0
Organic pear puree for infants	Pear Williams 100%	Organic Baby Food	-	-	-	5	5	5	5	5,0
Organic apple-banana compote	Apple 75%, banana 25%	Organic	-	-	-	4	5	5	5	4,8
Organic apple-kale smoothie	Yellow beetroot juice*, grape juice*, mango pulp*, apple pulp* (10%), cucumber juice*, lactic acid fermented, orange juice*, green cabbage* (4%), spinach*, lemon juice*, ginger extract*. *from organic farming.	Organic	-	-	-	4	5	5	5	4,8
Organic four-grain cakes with sesame	Whole rice (Italy), maize (Italy), millet (North America, China, Europe), buckwheat (China, Europe), sesame 1% (India, Peru, Africa). All ingredients are organically grown.	Organic	-	-	-	4	5	5	5	4,8
Organic whole-grain rolled oats	Organic oat flakes	Organic	-	-	Flakes	4	5	5	4	4,5



Supplementary Figure 1. Scatterplot showing the relationship between the FNI values and mean perceived naturalness for 30 food products