Agriculture and Food

http://www.aimspress.com/journal/agriculture

AIMS Agriculture and Food, 5(1): 54–75.
DOI: 10.3934/agrfood.2020.1.54
Received: 20 September 2019
Accepted: 12 December 2019
Published: 12 February 2020

*Research article*

# The sustainability of Novel foods in the transition phase to the circular economy; the trade "Algae fit for human consumption" in European Union

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**Abstract:** The European Parliament Resolution of 2012 on the Resource Efficient Europe 2020 Programmed has stimulated the analysis proposed in this document. In particular, the paper takes its cue from the planned initiatives regarding the circular transition of the economy, i.e. the minimization of waste and environmental impacts generated by the use of materials and resources. The analysis takes as a reference the algae for human consumption that the EU includes among the first products recognized as "Novel food" within the food or ingredients of non-EU origin consumed in a non-significant way before 1997 (Regulation (EC) 258/1997) [1]. Assuming the sustainability of human consumption of algae, our paper aims to identify elements of physical and economic measurement of circularity in the supply phase of the initial production cycle. The prevalent extra-European origin of the algal virgin matter suggested to determine such as indicator the "balance of the resource" from the trade quotas extra EU of algae (Primary raw materials) and of the relative first food derivatives, i.e. agar agar and carrageenan (Secondary raw materials). This is in view of the fact that the European Commission considers the trade quotas as information of the measurability of the circularity of resources at the macro level (country system). The results obtained in our analysis, through the indices of sectoral specialization, show-interesting levels of sustainability of algae by member country. While by positive results of recent years of the material trade balance and the economic trade balance, emerge appropriate elements of the measurability of the circularity of the food sector under examination. These results confirm that business around the algae sector in the European Union shows virtuous processes regarding economic, social and environmental sustainability. These data are also preparatory to the launch of further analyses of different structural levels of the sector itself. In fact, the measurability of the circularity that the document proposes consists of an approach that combine with other tools for assessing the country system. Tools whit, as a whole, however must have a point of convergence with the evaluation of the economic and environmental sustainability of the micro reference systems (algae chains systems), with their own balance of circularity and from the perspective of governance processes of circularity of resources.

**Keywords:** novel food; algae fit for human consumption; circular economy; trade

## 1. Introduction

The affirmation and consolidation of international relations in the world has favored the use of new natural products in the EU food sector, encouraging industrial policies aimed at activating business models for innovative food products. Indeed, production initiatives are not always in line with the operating rules and physical and climatic limits that the EU itself promotes towards the circular transition of the economy, i.e. in the direction of minimizing waste and environmental impacts. For this reason, in recent years, initiatives are underway in the EU (European Parliament Resolution of 2012 on “Resource Efficient Europe” 2020 Program) [2] to acquire information on the use of “resources”. This with the aim of developing a set of indicators to measure the performance of “circularity”, both at the micro level as a tool to be applied to the business system and other public and private activities and at macro level as a tool to be applied to the country system.

The opening up of the traditional economy to the international economy has brought about an improvement in the living standards of millions of people in those countries that have benefited above all from the evolution of the World Trade Organization (WTO) Agreements. The reduction of regulatory barriers (tariff and fiscal) has influenced the growth of innovative consumption models (public opinion) and the accentuation of speculative flows of medium-short time (agri-food companies and stakeholders). The free movement of goods has stimulated transactions from and to the European Union of raw materials transferable to food processing [3].

In order to regulate the placing on the internal market of novel foods and food ingredients (novelfoods), even if not used to an ‘appreciable’ extent, the Community legislator established Regulation (EC) No 258/97 [1,4]. In particular, since 15 May 1997, this Regulation considers food traditionally used in the EU to be safe, while foods that do not have a tradition in the EU become novel foods following a specific authorization of the unilateral member states. Subsequently, this authorization is instructed by Regulation (EU) 2015/2283, which provides for the centrality of technical, scientific and administrative assessment procedures, so as to overcome market disputes between member countries and to ensure consumers’ health food in the use of Novel foods [1,5,6].

In this evolutionary context, Seaweed for fit for human consumption (hereinafter, FHC) have found space to assert their presence on the European Union market, also through premonitory of a set of traceable new food products (Regulation (EC) 258/1997 and Regulation (EU) 2015/2283) for which market demand is growing strongly in the EU. This is happening in a context where the EU is poor in algae cultivation, so the relative traceability from the point of origin is an evidence that demonstrates the effectiveness of the resource in terms of economic and environmental sustainability [1].

This sustainable framework also applies to the semi-finished products (agar agar agar and carrageenan) of the first industrial processing of FHC, since as a second raw material they participate as integrators of a large number of foods included in the list of Novel Food (Regulation (EU) 2017/2470 establishing the Union list of novel food).

These are a number of food products for which the traceability of the original raw material is also important in the context of the circular transition of the economy.

In this regard, a certain importance is given to the initial supply flow as the primary productive dimension of the production cycle, for this aspect, intended as a functional tool through which it is possible to identify indicators of initial circular measurability [7].

In this respect, international trade can provide the basis for an initial determination of the circular measurability of the economy with regard to raw materials of non-EU origin, as it is difficult to identify other indicators that are valid for the assessment under consideration. However, trade quotasare the measurability tools adopted by the European Commission in the Roadmap of the "Resource Efficient Europe" 2020 Program in the case of references at macro level, i.e. at country system level.

This circumstance is considered effective since the related international trade, like any other macro-economic activity expressing a balance sheet, provides precise elements of measurable circularity of the economy of the individual EU member country [8,9].

In essence, physical and economic flows of "Primary raw materials" (algae) and "Secondary raw materials" (agar agare carrageenan), represent basic information elements for the period 2012–2018.

## FHC: A short overview

The Eastern countries were the first to recognize the peculiarities of FHC, while the Western countries have a relatively new legacyof these superfoods, mainly of change from the initial condition of use of FHCs: i.e., dried, flaked, compressed or powdered [9].

In fact, algae are among the renewable natural resources that can also be used by transforming them into final or intermediate goods and services (bio economy), elements that effectively represent the food of the future because they are sustainable and nutritious (Figure 1).

Saltwater or freshwater algae are real super food (Figure 2), in fact, they contain all the essential amino acids and their protein content is considerable, with percentages reaching 60% [10]. The properties that many algae possess make them not only an excellent food (a mix of vitamins and minerals, proteins, fats, carbohydrates and fibres) and dietary supplements, but also the raw material for the nutraceutical and pharmaceutical industries [11].

In response to rising global demand, new cultivation initiatives are taking place in the European Union, contributing to the increase in the global production of seaweed.

In nature there are many types of algae, divided into more than 25 thousand species that differ according to their greater or lesser structure [12]. In fact, there are many multi-cellular (giant or macroscopic algae) and unicellular (phytoplankton or microscopic algae) [13]. Algae live in different aquatic habitats in the world (Figure 3) and grow in different depths, which determines the color of plant pigments (percentage of chlorophyll). Therefore, there are macroscopic species that live on the surface (green algae), in depth (red algae) and at an intermediate depth (brown or brown algae). On the other hand, in almost all aquatic habitats there are unicellular prokaryotes blue-green algae, or green-blue algae, for their virtue of being essential for living organisms as nitrogen fixers. The European Union recognizes Chlorella (blue-green algae) and Spirulina (green-blue algae) for the use of the latter types of algae in food.

Algae have numerous uses [14] in food directly in their original state (the well-known brown alga Nori for sushi, etc.) or subjected to extraction (red and brown algae); stabilizing phyco colloids-thickeners and gelling-food, among the best-known agar agar, carrageenan and alginates [15]. Algae are used in cattle feed to help reduce carbon dioxide emissions [16].

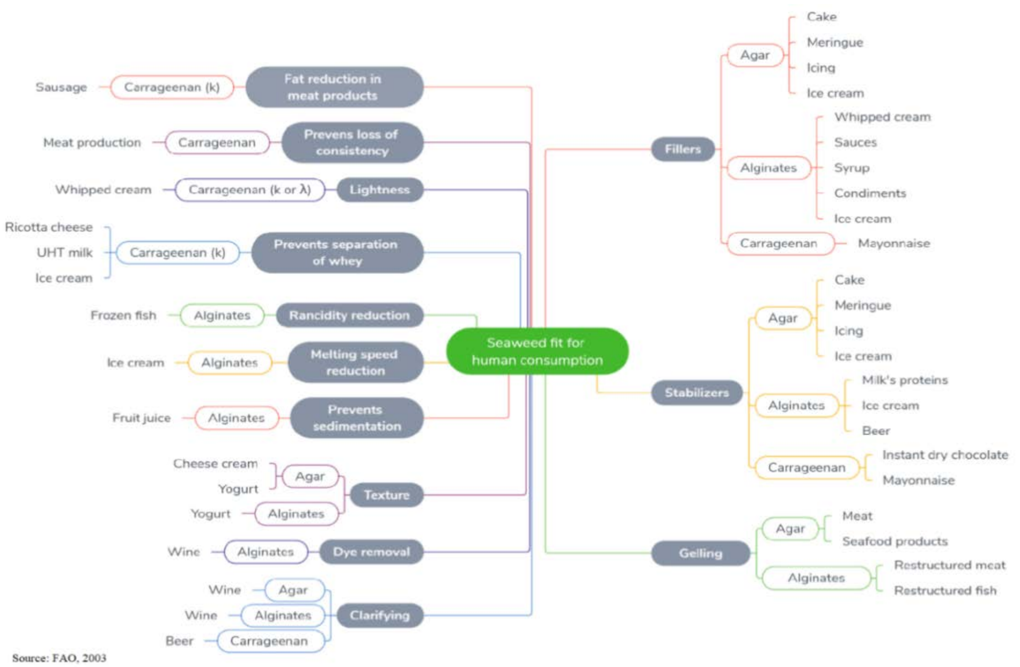



**Figure 1.** Our elaboration to describe "Primary raw materials" (Seaweed fit for human consuption) and "Secondary raw materials" (agar agar agar agar, carrageenan and alginates). Source: Information and data from FAO's 2003 document (Guide to the Seaweed Industry) [17].

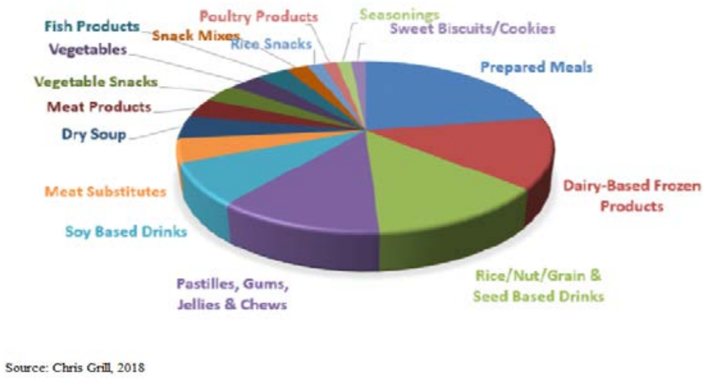
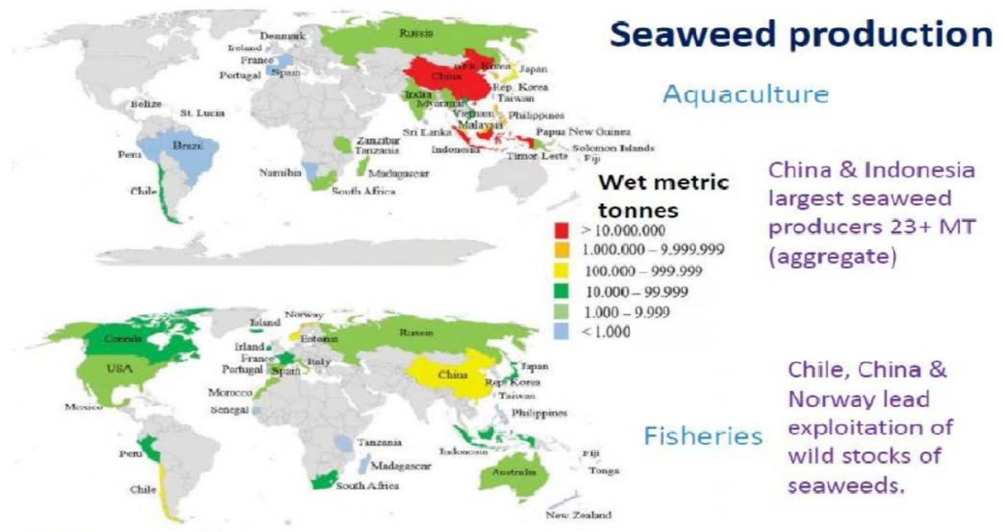



**Figure 2.** Distribution of the main uses of Seaweed fit for human consuption, such: Ingredients (such as hydrocolloids extracted or whole ingredients), nutritions (minerals, vitamins, antioxidants) and lavour. Scheme taken from: Typical use in food (Ulster University: Marine bio actives and health: Functional Foods) [18].




Source: Chris Grill, 2018

**Figure 3.** Global seaweed production. Distribution of the main forms of cultivation and average harvested quantities of algae in the world, such: Aquaculture and Fisheries. Scheme taken from: Typical use in food (Ulster University: Marine bio actives and health: Functional Foods) [18].

## 2. Materials and methods

The analysis took as a reference the imports and exports of EU member countries, for the period from 2012 to 2018, from the Yearbook database of trade statistics (UN Comtrade). In particular, the database refers to the codes of the Harmonized System (HS), i.e. the international standardized six-digit system of names and numbers. In particular, the coding system [1,19,20]:

-HS 121221 Seaweeds and other algae; fit for human consumption, fresh, chilled, frozen or dried, whether or not ground");

-HS 130231 Agar-agar;

-HS 130239 Carrageenan Mucilages and thickeners nes.

As for alginates, we believe that they are included in HS 130239, i.e. within the scope of Mucilages and thickeners nes. However, we believe that the lack of distinction between the two semi-finished products does not affect the examination of the data on carrageenan.

A first important element of knowledge of the territorial context in which the reference production process is located is the determination of the sectoral specialization [21] of a country in relation (EU Member States) to the total of countries that make up the corresponding aggregate economic system (see European Union).

In this respect, the Lafay index (French economist Gerard Lafay) consists of comparing a country's normalized net export balance with the European Union's normalized aggregate net export balance.

In particular, in the expression shown below, the index i indicates a specific country; the variables x and m represent-respectively-the monetary value of exports e of imports of products from sector j, while Σj is la total sum, of import and export, for a group of countries (i = 1, 2, n). That is for the countries for which we intend to study the degree of specialization [20,21]:

$$IS_j = \left[ \frac{x_j^i - m_j^i}{x_j^i + m_j^i} - \frac{\sum_j x_j^i - \sum_j m_j^i}{\sum_j x_j^i + \sum_j m_j^i} \right] \times \left[ \frac{x_j^i + m_j^i}{\sum_j x_j^i + \sum_j m_j^i} \right] \times 100 \quad (1)$$

The Lafay index takes "−, 0, +" values. The result of the index if it is included in the contribution:
-positive, indicates that the country is relatively specialized;
-negative, indicates that the country is de-specialized;
-zero, indicates that the country equals exports to imports.

The production specialisation index, highlighting the importance of the resources considered in the reference territorial context, provides different degrees of validity to the indicators of measurability of circularity through the determination of the commercial balance sheet on physical values and economic values [22], in particular:
-Physical trade balance-PTB, is obtained by subtracting from the actual weight of imports that of exports: Import > Export = positive value of physical surplus of resource; Import < Export = negative value of physical deficit of resource;
-Economic trade balance: is obtained by subtracting the value of exports from the economic value of imports: Import > Export = positive balance; Import < Export = negative balance.

In addition, in order to measure and monitor the circular economy [23,24] in the reference production system, the Circularity Index and the Pricing Index [7] can provide useful indications.

In particular, the Circularity Index (CI) is the ratio of imported (purchased) ($V_{mps}$) second hand raw materials to total second hand raw materials and original raw materials, expressed in physical terms (volumes) ($V_{mpt}$ ):

$$CI = V_{mps}/V_{mpt} \times 100 \quad (2)$$

The second raw materials is represented by the aggregate of semi-finished agar agar and carrageenan products; an interpretation in relation to the impossibility of being able to distinguish the types of virgin algae from which these semi-finished products derive.

The CI index can vary between 0 and 100%. The closer the index is to the highest value, the higher the level of circularity of the production system under examination.

As for Pricing Incidence (PI), within the virgin raw material, although not distinguishing in Un Comtrade the different types of algae, it was chosen to determine the PI index for the semi-finished agar agar and carrageenan products. So that the index thus determined, albeit with limited precision, can provide useful indications on the use of possible structural interventions by type of semi-finished product. In fact, the economic convenience of purchasing finished semi-finished products on international markets would favour fewer techno-economic strategies based on cycles of "reuse-repair-restoration" of products and resources. In essence, to guarantee to the economic systems of the Member States, levels of circularity in the use of the type of algal product used.

The prices of algae, of agar agar and of carrageenan were calculate by the ratio of their monetary values to the quantities extrapolated from the UN Comtrade source.

Pricing Incidence (PI): The ratio of the price difference of the second raw material and the initial raw material to the price of the second raw material. In particular:

$$PI = [(Pmps - Pmpi)/Pmpi] \times 100 \quad (3)$$

The index PI can have a positive or negative value; the purchase of the second raw material is convenient compared to the virgin raw material when the index is negative.

Interesting is the fact that the indices under analysis allow comparisons between the member countries of the European Union, through the use of a graphic approach that has in the immediacy one of its main positive characteristics [25].

In addition, the average annual growth rate applied import and export trade of the algae at the level of the EU member country provides information on the prospects for development of the algae sector in the period under review; in particular:

$$[(b/a)(1/n) - 1] \times 100 \quad (4)$$

In particular, *b* is the value of the last year, *a* is the value of the first year, *n* is the number of years.

Finally, other indicators should supplement the results achieved by the sustainability and circularity indicators indicated above. In order to measure the full circularity of products and resources, in fact, it is necessary to combine the previous indicators with other indicators, among all the health and safety indicators that the products themselves must be able to guarantee.

## 3. Results and discussion

A first important point of reference to highlight is the world production of algae. The data, to 2016 [25] indicate a volume of seaweed equal to 30 million tons, for a value of 11.6 billion dollars. Asia is the main producer, led by China (14 million tons for a value of 8.6 billion dollars) and Indonesia (11 million tons for a value of 1.3 million dollars), and followed by the Philippines and the Republic of Korea. For the evolutionary aspects of the sector, the size of the aquaculture of marine algae is growing, while the volume of marine algae in the last decade has remained almost unchanged (in fresh weight, from 1.06 million tons in 2006 to 1.09 million tons in 2015).

In Europe, the collection of algae in 2016 is equal to 293324 tons; among the 28 member countries are interesting the initiatives underway in France for the aquaculture of seaweed and the volume of wild seaweed, equal to 18.7% of the total European Union.

The European Union's FHC trade with third countries declares flows in a dynamic trend.

The decrease in the volume of imports into the EU, around 17% in the period 2012–2018 (Table 1). The low interest of the first processing industry in the production of semi-finished products, agar agar and carrageenan corresponds to the decrease in the volume of imports into the EU, around 17% in the period 2012–2018 (Table 1). One of the reasons for the drop in imports is the increase in FHC supply within the European Union due to the new FHC crops recently cultivated in some Member States.

On the other hand, exports of FHC increased by just over 5% in the seven-year period examined. In this area of trade, a number of factors contribute to the upward trend. Re-exports within the EU, transfers to third countries of FHC of the EU offer with local quality characteristics and, not least, food preparations with FHC in its natural state. Even the world's leading algae producers appreciate food preparations with algae from the Old Continent.

The recent EU legislative measures on Novel Food may have influenced the highlighted trade trends of the member countries [26] which, driven to activate new food initiatives, i.e. to increase the levels of business already underway, are moving from traditional production technologies to innovative improvement measures.

The economic values (Table 2), denounce annual rates of change mainly positive financial, both for import and export. Whatever the entity of the movements, the composition effect triggered by globalization is relevant. In fact, FHC transactions of different qualities would affect the level of average prices. Moving on to the positioning of the production specialization of the individual 28 member countries within the European Union, the results of the Lafay index, for FHC, are shown in Figure 4.The dynamics of the 2012–2018 period, of the Lafay index, develops along the axis of the abscissa; in fact, the member countries oscillate between positive and negative values not far from each other. The Netherlands and France differ from these trends; that is, in the first years of the seven-year period under examination, the Netherlands shows clear signs of sectoral production specialization, France strong specialization. Subsequently, for both these latter countries, there is a progressive tendency to conform to the other EU member countries. The result is a profile of the production system that expresses an evolving structural technological condition that affects the member countries of the European Union to varying degrees. However, the member countries located to the north of the EU represent the positive condition of the Lafay index; moreover, some of the latter countries would be interested in local seaweed farming businesses [27].

Turning to semi-finished products, the Lafay index, referring to agar agar, takes on particular significance starting from half of the seven-year period under examination (Figure 5), i.e. when most of the Member States (twenty in number) report conditions favourable to sectoral production specialization. This condition highlights the existence of a strengthening of technological innovation in this sector. Italy is the only country in the European Union, which, according to the statistics used, is not interested in importing agar agar. For carrageenan, in the period 2012–2018, the Lafay index shows only positive levels of sectoral production specialization in 5 countries compared to the total for the European Union; in fact, Figure 6 shows a widespread evolution of production de-specialization in the case of countries with lower technological intensity in the use of semi-finished products as integrators in food production.

The different levels of business highlighted by Lafay's indices, both by products and by countries, can be useful for the introduction of sustainable management tools for production processes, products and territories that is that take into account the challenge of the circular economy. In this direction, the measurement of circularity provides useful elements of evaluation of management tools starting from the procurement phase of production processes. In this direction of common environmental sustainability, the identification of management tools supports the measurement of product circularity, which in our case refers to the procurement phase of production processes. Thus, the annual growth rate of the Physical trade balance indicator, referred to FHC (Table 3), in the period 2012–2018, the resource deficit would reveal favourable circumstances for the manufacture of semi-finished products, albeit with different intensity within member countries. This result is in line with the corresponding FHC sectoral production specialization index, which covered the largest number of EU member countries.

**Table 1.** Import and export Seaweeds and other algae; fit for human consumption, fresh, chilled, frozen or dried, whether or not ground (HS 121221), 2012–2018.

| Countries | Code | Weight in tonnes Import | | | | | | | Export | | | | | | | Growth rate in the seven-year period 2012–2018 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | | |
| Austria | AT | 694.227 | 1037.26 | 903.929 | 1025.388 | 1067.831 | 1032.413 | 1279.594 | 49.561 | 73.329 | 94.465 | 169.186 | 163.274 | 105.575 | 82.244 | 9.128622 | 7.50371 |
| Belgium | BE | 260.423 | 194.851 | 312.404 | 365.958 | 318.751 | 350.288 | 437.591 | 127.369 | 119.708 | 169.264 | 112.799 | 172.648 | 196.308 | 220.344 | 7.695718 | 8.144729 |
| Bulgaria | BG | 0.508 | 13.919 | 16.716 | 11.467 | 12.951 | 8.789 | 11.61 | 1.619 | 2.293 | 3.866 | 4.007 | 6.927 | 2.953 | 4.658 | 56.36457 | 16.29597 |
| Croatia | HR | 2.699 | 3.893 | 1.332 | 1.417 | 1.603 | 5.042 | 3.103 | .. | .. | .. | .. | .. | .. | .. | 2.012673 | .. |
| Cyprus | CY | 15.483 | 8.15 | 14.602 | 7.381 | 11.233 | 19.518 | 26.571 | – | 0.669 | – | 0.52 | .. | 2.327 | 0.659 | 8.020838 | −0.21492 |
| Czechia | CZ | 72.548 | 95.698 | 47.639 | 59.235 | 62.641 | 80.317 | 86.105 | 32.438 | 23.813 | 9.784 | 10.46 | 34.995 | 122.55 | 45.278 | 2.47761 | 4.879462 |
| Denmark | DK | 149.892 | 117.639 | 183.179 | 188.352 | 167.417 | 136.615 | 115.532 | 597.204 | 548.661 | 356.003 | 368.816 | 353.074 | 368.669 | 482.028 | −3.65121 | −3.01444 |
| Estonia | EE | 7.769 | 9.888 | 11.947 | 11.317 | 5.744 | 8.951 | 40.875 | 1.563 | 10.32 | 1.048 | 0.674 | 1.29 | 1.937 | 0.984 | 26.76905 | −6.39676 |
| Finland | FI | 21.802 | 40.965 | 35.341 | 40.935 | 71.772 | 56.415 | 45.175 | .. | .. | .. | .. | .. | .. | .. | 10.96864 | .. |
| France | FR | 16.05499 | 13.06768 | 11.01281 | 3.246384 | 3.481941 | 2.870476 | 917.927 | 911.843 | 914.542 | 824.007 | 973.553 | 991.176 | 716.98 | 526.278 | 78.2495 | −7.55162 |
| Germany | DE | 761.464 | 1.225754 | 1.113616 | 1.377155 | 1.372849 | 2.035243 | 1.612563 | 376.629 | 731.046 | 505.996 | 675.024 | 712.055 | 345.654 | 973.953 | −58.5064 | 14.53714 |
| Greece | GR | 18.897 | 23.972 | 75.835 | 47.7 | 14.029 | 11.185 | 18.807 | 1.994 | 0.567 | 0.542 | .. | 0.735 | 0.707 | 1.984 | −0.06818 | −0.0718 |
| Hungary | HU | 36.48 | 0 | .. | .. | .. | 0.896 | .. | 36.48 | .. | .. | .. | .. | 0.896 | .. | −41.1107 | −41.1107 |
| Ireland | IE | 29.62485 | 13.70678 | 1.518483 | 1.330098 | 10.225 | 20.273 | 33.314 | 579.093 | 480.547 | 1190.054 | 687.046 | 432.509 | 758.426 | 322.765 | 1.690767 | −8.0114 |
| Italy | IT | 303.921 | 398.693 | 501.012 | 496.421 | 581.487 | 577.811 | 474.21 | 10.554 | 20.68 | 29.889 | 22.182 | 20.959 | 20.636 | 7.382 | 6.561771 | −4.97838 |
| Latvia | LV | 61.62 | 57.781 | 52.362 | 60.705 | 62.305 | 25.405 | 79.069 | 53.595 | 56.836 | 48.02 | 60.67 | 63.091 | 51.082 | 77.621 | 3.626116 | 5.433659 |
| Lithuania | LT | 31.561 | 35.21 | 56.412 | 51.104 | 46.625 | 111.966 | 47.935 | 40.43 | 30.761 | 39.749 | 50.899 | 54.162 | 133.236 | 36.317 | 6.152164 | −1.52097 |
| Luxembourg | LU | 2.863 | 11.726 | 14.925 | 15.338 | 20.747 | 3.562 | 17.821 | 0.536 | 0.613 | 0.618 | 1.017 | 0.617 | 1.532 | 1.646 | 29.85073 | 17.3841 |
| Malta | MT | 2.518 | 1.828 | 3.599 | 3.303 | 10.619 | 0 | 42.604 | – | – | – | – | – | – | – | 49.79073 | – |
| Netherlands | NL | 365.88 | 303.689 | 264.907 | 456.196 | 262.452 | 218.154 | 121.701 | 395.366 | 368.269 | 380.613 | 198.159 | 194.999 | 188.16 | 244.777 | −14.5508 | −6.62018 |
| Poland | PL | 403.909 | 323.399 | 538.23 | 556.329 | 708.311 | 541.059 | 245.113 | 2.173 | 1.618 | 0.372 | 2.482 | 166.212 | 159.727 | 244.213 | −6.88668 | 96.31724 |
| Portugal | PT | 79.368 | 46.891 | 67.112 | 52.755 | 77.63 | 104.224 | 109.661 | 79.11 | 42.668 | 82.215 | 19.829 | 34.877 | 83.962 | 186.484 | 4.726866 | 13.03201 |
| Romania | RO | 59.795 | 46.268 | 32.568 | 45.083 | 55.83 | 38.976 | 56.299 | .. | 2.922 | 2.435 | .. | 4.814 | 7.412 | 4.467 | −0.85695 | 6.251159 |
| Slovakia | SK | 12.987 | 18.587 | 14.653 | 10.958 | 0 | 0 | 0 | 8.619 | 8.904 | 5.9 | 12.762 | 6.732 | 6.85 | 20.286 | −2.39763 | 13.00708 |
| Slovenia | SI | 14.423 | 4.334 | 5.655 | 5.158 | 2.563 | 1169.494 | 2.879 | 4.472 | 6.364 | 4.418 | 1.936 | 3.362 | 119.781 | .. | −20.5623 | 59.94981 |
| Spain | ES | 224.529 | 255.783 | 431.946 | 603.901 | 591.109 | 541.959 | 559.286 | 272.372 | 236.725 | 202.151 | 454.651 | 237.938 | 153.081 | 138.744 | 13.92606 | −9.18653 |
| Sweden | SE | 178.494 | 131.251 | 153.06 | 185.95 | 179.307 | 193.283 | 216.26 | 20.413 | 15.034 | 17.349 | 45.48 | 74.961 | 89.507 | 106.462 | 2.779739 | 26.61049 |
| United Kingdom | GB | 909.169 | 2340.012 | 5639.895 | 7051.851 | 6029.321 | 6502.182 | 7957.465 | 874.572 | 1031.938 | 1328.73 | 1556.467 | 1882.028 | 2192.242 | 2704.392 | 36.32955 | 17.50035 |
| EU28 | | 50.37306 | 33.5219 | 23.02417 | 17.30786 | 15.22731 | 16.12254 | 13.99985 | 4.480848 | 4.72889 | 5.297611 | 5.429576 | 5.614141 | 5.830529 | 6.434441 | −16.7162 | 5.305265 |

Source: Un Comtrade.

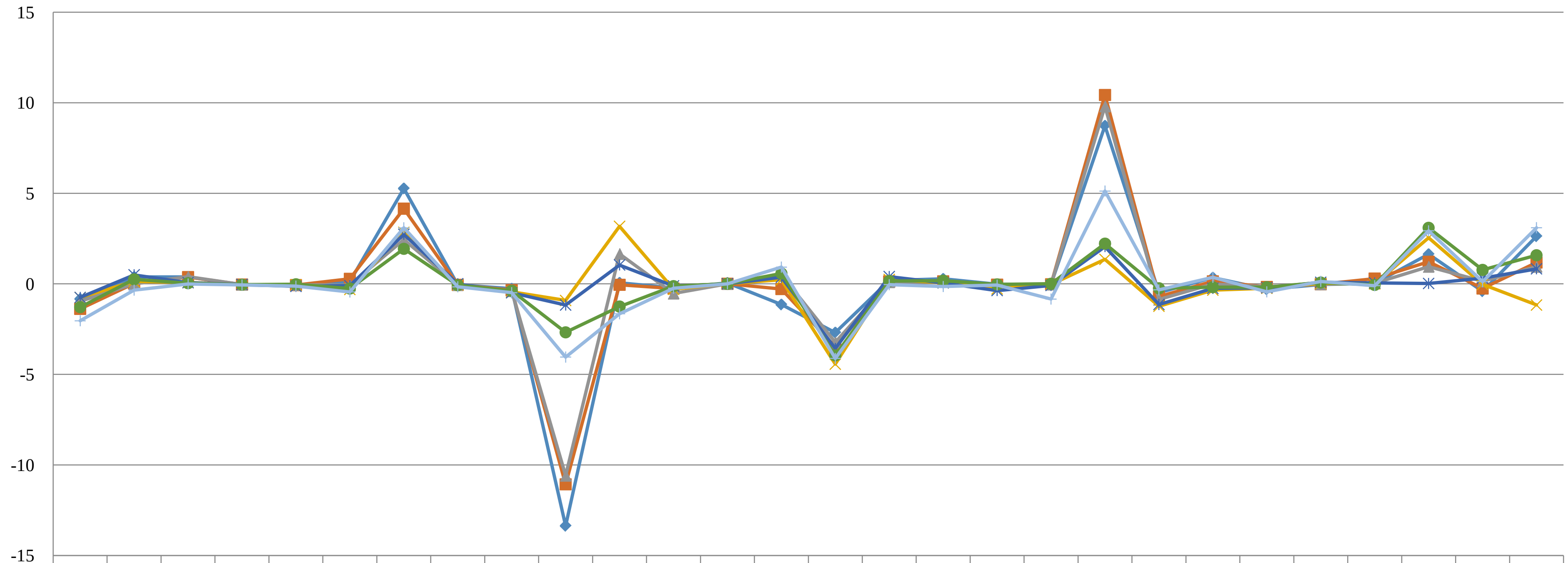
**Table 2.** Import and export Seaweeds and other algae; fit for human consumption, fresh, chilled, frozen or dried, whether or not ground (HS 12122), 2012–2018.

| Countries | Code | Weight in tonnes | | | | | | | | | | | | | | Growth rate in the seven-year period 2012–2018 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Import | | | | | | | Export | | | | | | | | |
| | | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | | |
| Austria | AT | 1.95636 | 3.465455 | 3.131234 | 3.214938 | 3.968878 | 4.688957 | 4.602296 | 0.319042 | 0.640551 | 0.827699 | 1.19069 | 1.450476 | 1.634741 | 1.539164 | 12.99913 | 25.20851 |
| Belgium | BE | 1.631935 | 1.92967 | 3.042913 | 2.385117 | 2.538754 | 3.19583 | 3.821463 | 1.005216 | 1.025141 | 1.626881 | 1.367785 | 1.646374 | 2.007746 | 2.544079 | 12.92486 | 14.18529 |
| Bulgaria | BG | 0.023797 | 0.150063 | 0.144694 | 0.138344 | 0.15235 | 0.074927 | 0.132868 | 0.270503 | 0.390402 | 0.418946 | 0.121688 | 0.124074 | 0.068919 | 0.090476 | 27.84971 | −14.4832 |
| Croatia | HR | 0.105225 | 0.071076 | 0.067642 | 0.065869 | 0.060924 | 0.073337 | 0.079451 | 0.005281 | 0.000914 | 0.002865 | 0.00321 | 0.002405 | 0.001849 | 0.002152 | −3.93424 | −12.0363 |
| Cyprus | CY | 0.16357 | 0.12167 | 0.091535 | 0.077747 | 0.209597 | 0.140012 | 0.188334 | 0 | 0.001655 | 0 | 0.001557 | 0.001755 | 0.060799 | 0.019612 | 2.034359 | 42.36038 |
| Czechia | CZ | 0.577746 | 0.600122 | 0.622463 | 0.84584 | 0.627788 | 0.802312 | 0.93852 | 0.347818 | 0.544674 | 0.271571 | 0.237176 | 0.243724 | 0.246087 | 0.280795 | 7.176838 | −3.01164 |
| Denmark | DK | 1.761944 | 2.026273 | 1.927681 | 1.646263 | 1.739934 | 3.818739 | 3.2356 | 4.426029 | 4.557058 | 3.163851 | 2.86566 | 2.885967 | 3.697559 | 5.348042 | 9.070916 | 2.740122 |
| Estonia | EE | 0.170219 | 0.187241 | 0.173157 | 0.105793 | 0.073353 | 0.17271 | 0.277768 | 0.042874 | 0.047463 | 0.040177 | 0.021027 | 0.03448 | 0.036097 | 0.052973 | 7.246228 | 3.067784 |
| Finland | FI | 0.406141 | 0.570407 | 0.65026 | 0.596123 | 0.753976 | 0.575182 | 0.61493 | 0.000884 | 0.000333 | 0.000641 | 0.007627 | 0.017671 | 0.021191 | 0.001049 | 6.104927 | 2.474924 |
| France | FR | 27.80123 | 25.9864 | 25.8655 | 9.360228 | 9.585361 | 11.47351 | 11.82837 | 3.512756 | 4.219066 | 4.582339 | 4.357484 | 3.984278 | 4.372971 | 5.089508 | −11.4925 | 5.439654 |
| Germany | DE | 6.611064 | 10.72162 | 5.274711 | 4.875183 | 5.91806 | 8.46429 | 8.476386 | 3.059552 | 5.550114 | 4.266023 | 4.820189 | 3.754972 | 3.79852 | 4.818046 | 3.614351 | 6.702182 |
| Greece | GR | 0.407031 | 0.46341 | 0.914639 | 0.416313 | 0.226124 | 0.229288 | 0.348636 | 0.027079 | 0.02216 | 0.024609 | 0.012609 | 0.025259 | 0.02583 | 0.031748 | −2.18801 | 2.298463 |
| Hungary | HU | 0.063402 | 0 | .. | 0.00057 | .. | 0.003133 | 0.003958 | 0.063402 | 0 | .. | 0.00057 | .. | 0.003133 | 0.003958 | −32.7162 | −32.7162 |
| Ireland | IE | 3.427251 | 1.851626 | 0.32349 | 0.31676 | 0.197404 | 0.271504 | 0.367188 | 0.778374 | 0.723521 | 0.616678 | 0.326096 | 0.366358 | 0.605899 | 1.143216 | −27.3191 | 5.644908 |
| Italy | IT | 4.420832 | 5.94861 | 5.62705 | 6.064749 | 6.157771 | 5.971435 | 5.317896 | 0.168361 | 0.159541 | 0.185322 | 0.142996 | 0.486444 | 0.247992 | 0.118028 | 2.674421 | −4.94754 |
| Latvia | LV | 0.354096 | 0.370895 | 0.359027 | 0.315459 | 0.322935 | 0.177939 | 0.387954 | 0.286815 | 0.305556 | 0.278996 | 0.336256 | 0.456695 | 0.219008 | 0.247657 | 1.313099 | −2.0752 |
| Lithuania | LT | 0.36191 | 0.360614 | 0.442612 | 0.322654 | 0.340313 | 0.558862 | 0.3976 | 0.353283 | 0.303868 | 0.349346 | 0.212865 | 0.209148 | 0.455612 | 0.157992 | 1.352651 | −10.8599 |
| Luxembourg | LU | 0.056253 | 0.103812 | 0.113769 | 0.387203 | 0.569386 | 0.101491 | 0.168645 | 0.008468 | 0.009901 | 0.011713 | 0.012483 | 0.012021 | 0.03094 | 0.061251 | 16.98179 | 32.66665 |
| Malta | MT | 0.023421 | 0.041482 | 0.056937 | 0.048434 | 0.13261 | 0 | 1.055248 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72.28595 | − |
| Netherlands | NL | 4.642396 | 4.192511 | 3.743635 | 5.363306 | 3.8151 | 3.478043 | 2.014353 | 8.122918 | 10.98529 | 10.56424 | 3.807169 | 3.437819 | 3.730035 | 6.341947 | −11.2437 | −3.47399 |
| Poland | PL | 0.82815 | 1.169186 | 1.417573 | 1.662442 | 2.676063 | 1.457035 | 1.595012 | 0.04281 | 0.015425 | 0.001726 | 0.023014 | 0.513441 | 0.627397 | 0.887145 | 9.815841 | 54.19284 |
| Portugal | PT | 0.497358 | 0.428115 | 0.919555 | 0.700147 | 0.867199 | 1.158622 | 1.74608 | 0.461538 | 0.335402 | 0.482173 | 0.131542 | 0.252417 | 0.509729 | 1.650576 | 19.65024 | 19.96682 |
| Romania | RO | 0.472444 | 0.329872 | 0.310438 | 0.322767 | 0.39293 | 0.337043 | 0.599355 | 0.004453 | 0.025019 | 0.019323 | 0.002252 | 0.03746 | 0.042374 | 0.031178 | 3.457498 | 32.05116 |
| Slovakia | SK | 0.208199 | 0.199049 | 0.145297 | 0.113097 | 0 | 0 | 0 | 0.067708 | 0.082639 | 0.063006 | 0.077966 | 0.061746 | 0.055118 | 0.123783 | −100 | 9.001274 |
| Slovenia | SI | 0.099443 | 0.166358 | 0.19378 | 0.134004 | 0.06876 | 0.101426 | 0.137472 | 0.061632 | 0.327945 | 0.13376 | 0.069652 | 0.069172 | 0.008922 | 0.003637 | 4.734903 | −33.2549 |
| Spain | ES | 1.677682 | 2.422523 | 4.900782 | 3.918736 | 5.054101 | 4.792 | 4.778 | 1.891373 | 2.292677 | 3.449197 | 3.867231 | 2.568317 | 2.453133 | 2.756347 | 16.12715 | 5.527401 |
| Sweden | SE | 1.118387 | 1.166283 | 1.210584 | 1.262392 | 1.418841 | 1.683744 | 2.14313 | 0.225982 | 0.391871 | 0.772873 | 0.650027 | 0.948071 | 1.561702 | 1.722894 | 9.736452 | 33.66767 |
| United Kingdom | GB | 4.938215 | 7.832468 | 12.49002 | 14.67562 | 17.02435 | 15.62749 | 10.86144 | 4.060192 | 5.078686 | 7.503093 | 7.020488 | 9.212981 | 10.10628 | 11.09028 | 11.91866 | 15.43627 |

Source: Un Comtrade.

**Table 3.** Circular economy measurement indices; Growth rate in the period 2012–2018.

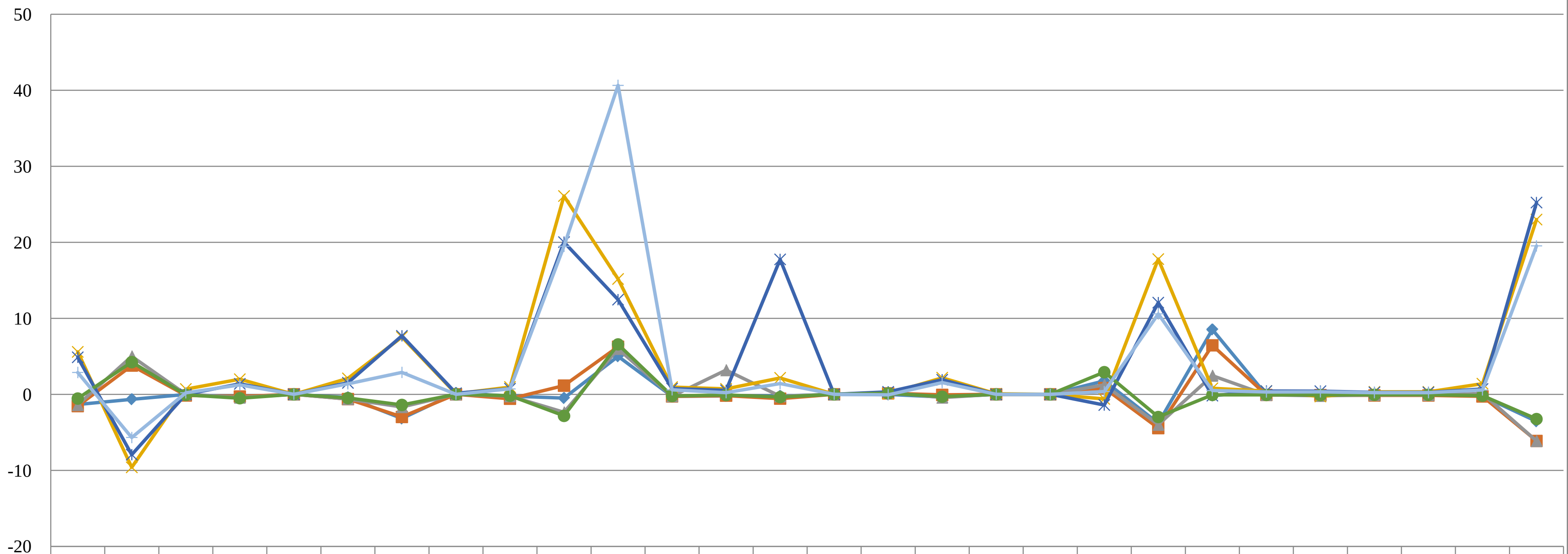
| Countries | Code | Physical trade balance | | | Economic trade balance | | |
|---|---|---|---|---|---|---|---|
| | | Algae | Agar agar | Carragenan | Algae | Agar agar | Carragenan |
| Austria | AT | 9.24771 | −2.52423 | −0.784063 | 9.36083 | 0.42687 | −0.473886 |
| Belgium | BE | 7.25511 | 63.4077 | −17.45855 | 10.7078 | −209.115 | −19.44972 |
| Bulgaria | BG | −229.948 | 6.81201 | 1.7082375 | −177.755 | 10.4337 | −2.268782 |
| Croatia | HR | 48.4685 | 6.55513 | 3.6171734 | −3.60387 | 8.77159 | 2.6787817 |
| Cyprus | CY | 7.63398 | 20.3573 | −8.293625 | 0.444 | 17.3577 | −6.622077 |
| Czechia | CZ | 0.25343 | −3.26176 | −3.263946 | 16.2004 | 7.40804 | .. |
| Denmark | DK | −2.80656 | −9.05277 | 2.8194644 | −3.26019 | −11.2458 | −0.777747 |
| Estonia | EE | 30.4481 | −176.63 | −0.210539 | 8.45706 | −184.495 | 4.4765004 |
| Finland | FI | 10.9384 | 5.04534 | 7.6952408 | 6.11208 | 6.77475 | 3.8168699 |
| France | FR | −40.6747 | −9.73716 | 27.962415 | −16.7364 | 10.4907 | 0.8837842 |
| Germany | DE | 7.5036 | 6.84767 | −27.31548 | 0.42427 | 32.3441 | −13.56647 |
| Greece | GR | −0.06775 | −0.06246 | −12.40008 | −2.55948 | 1.34297 | −6.783792 |
| Hungary | HU | .. | −7.69891 | 2.8164354 | .. | −9.39661 | 2.0958001 |
| Ireland | IE | −151.769 | 31.9289 | 8.0205404 | −183.913 | 19.5497 | 18.523714 |
| Italy | IT | 6.86139 | −5.03032 | −7.963512 | 2.91501 | .. | −7.357709 |
| Latvia | LV | −21.7002 | 2.92848 | 10.021888 | 11.0692 | −185.242 | 12.718507 |
| Lithuania | LT | −203.932 | 13.8096 | −0.162604 | 60.7809 | 8.63997 | 3.2639385 |
| Luxembourg | LU | 31.9145 | −35.9694 | 1.9201413 | 12.2642 | −4.25958 | 20.342438 |
| Malta | MT | 49.7907 | 2.05717 | −0.140073 | 72.286 | .. | 4.4038268 |
| Netherlands | NL | 22.6453 | 8.62706 | 42.66304 | 3.16077 | −189.822 | 6.9128889 |
| Poland | PL | −58.1716 | 8.69213 | −8.590927 | −1.47277 | 4.08671 | −1.211612 |
| Portugal | PT | −325.637 | −158.98 | −13.00666 | 15.0383 | −165.674 | −1.600119 |
| Romania | RO | −1.94462 | 6.9475 | −246.8094 | 2.80995 | 8.16967 | 3.0198439 |
| Slovakia | SK | −224.53 | 10.0509 | −6.570253 | −198.207 | 5.81497 | −4.309931 |
| Slovenia | SI | −17.3933 | −205.275 | −4.42293 | 19.7903 | 6.34556 | 0.1583101 |
| Spain | ES | −236.413 | −296.293 | 10.045541 | −237.851 | 6.34556 | 9.1115412 |
| Sweden | SE | −5.07342 | 29.3549 | 1.5756234 | −10.2001 | 2.00249 | −4.31009 |
| United Kingdom | GB | 104.939 | 25.5192 | −20.36986 | −182.523 | 10.3213 | −26.927 |




| | AT | BE | BG | HR | CY | CZ | DK | EE | FI | FR | DE | GR | HU | IE | IT | LV | LT | LU | MT | NL | PL | PT | RO | SK | SI | ES | SE | GB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | -0.83 | 0.377 | 0.377 | -0.06 | -0.10 | 0.121 | 5.264 | -0.05 | -0.26 | -13.3 | 0.056 | -0.23 | 0.050 | -1.14 | -2.69 | 0.181 | 0.273 | -0.02 | -0.01 | 8.725 | -0.48 | 0.340 | -0.30 | -0.04 | 0.023 | 1.635 | -0.41 | 2.622 |
| 2013 | -1.38 | 0.021 | 0.369 | -0.04 | -0.07 | 0.274 | 4.146 | -0.06 | -0.35 | -11.0 | -0.05 | -0.26 | 0 | -0.28 | -3.49 | 0.132 | 0.137 | -0.05 | -0.02 | 10.42 | -0.70 | 0.132 | -0.17 | -0.02 | 0.285 | 1.218 | -0.25 | 1.173 |
| 2014 | -0.96 | 0 | 0.391 | -0.03 | -0.05 | -0.07 | 2.442 | -0.06 | -0.39 | -10.5 | 1.654 | -0.53 | 0 | 0.508 | -3.23 | 0.099 | 0.129 | -0.05 | -0.03 | 9.803 | -0.86 | -0.01 | -0.16 | -0.01 | 0.034 | 0.948 | 0.143 | 0.943 |
| 2015 | -0.75 | 0.134 | 0.068 | -0.04 | -0.05 | -0.30 | 2.845 | -0.05 | -0.44 | -0.91 | 3.175 | -0.3 | 0 | 0.224 | -4.43 | 0.240 | 0.058 | -0.27 | -0.03 | 1.350 | -1.23 | -0.34 | -0.24 | 0.025 | -0.00 | 2.541 | -0.03 | -1.17 |
| 2016 | -0.75 | 0.493 | 0.064 | -0.03 | -0.14 | -0.1 | 2.728 | -0.00 | -0.49 | -1.17 | 1.038 | -0.12 | 0 | 0.362 | -3.57 | 0.399 | 0.050 | -0.37 | -0.09 | 2.052 | -1.14 | -0.25 | -0.21 | 0.084 | 0.046 | 0.018 | 0.313 | 0.825 |
| 2017 | -1.28 | 0.247 | 0.033 | -0.05 | -0.02 | -0.26 | 1.933 | -0.07 | -0.38 | -2.68 | -1.25 | -0.13 | 0 | 0.569 | -3.95 | 0.149 | 0.175 | -0.03 | 0 | 2.217 | -0.25 | -0.18 | -0.18 | 0.069 | -0.06 | 3.092 | 0.765 | 1.576 |
| 2018 | -2.04 | -0.35 | -0.01 | -0.06 | -0.13 | -0.45 | 3.092 | -0.16 | -0.49 | -4.04 | -1.65 | -0.24 | 0 | 0.920 | -4.12 | -0.04 | -0.15 | -0.07 | -0.84 | 5.123 | -0.33 | 0.357 | -0.44 | 0.131 | -0.10 | 2.926 | 0.117 | 3.097 |

Source: UN Comtrade.

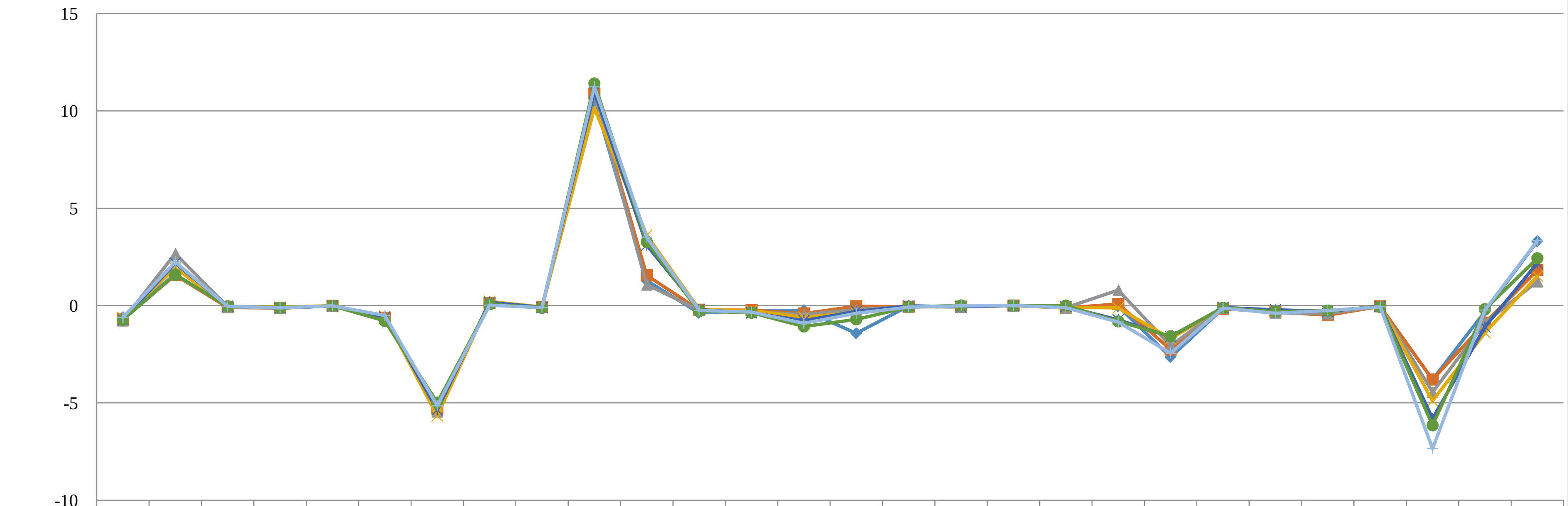
**Figure 4.** International sector specialization dynamics Seaweed for fit for human consumption (FHC) in the Membar countries; Lafay index [1].




| | AT | BE | BG | HR | CY | CZ | DK | EE | FI | FR | DE | GR | HU | IE | IT | LV | LT | LU | MT | NL | PL | PT | RO | SK | SI | ES | SE | GB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | -1.33 | -0.64 | 0 | -0.32 | 0 | -0.39 | -3.17 | 0.183 | -0.21 | -0.48 | 5.003 | -0.25 | -0.20 | -0.19 | 0 | 0 | -0.34 | 0 | 0 | 1.784 | -3.79 | 8.527 | -0.08 | -0.10 | -0.05 | -0.05 | -0.22 | -3.54 |
| 2013 | -1.54 | 3.780 | -0.14 | -0.28 | 0 | -0.62 | -2.98 | 0 | -0.58 | 1.138 | 6.260 | -0.27 | -0.17 | -0.57 | 0 | 0.133 | -0.07 | 0 | 0 | 0.825 | -4.43 | 6.439 | -0.08 | -0.10 | -0.14 | -0.14 | -0.26 | -6.12 |
| 2014 | -1.39 | 4.998 | 0 | -0.42 | 0 | -0.61 | -1.66 | 0 | -0.23 | -2.36 | 5.985 | -0.23 | 3.184 | -0.24 | 0 | 0.264 | -0.42 | 0 | 0 | 1.238 | -3.99 | 2.461 | -0.07 | -0.19 | -0.07 | -0.07 | 0.091 | -6.13 |
| 2015 | 5.585 | -9.59 | 0.692 | 1.988 | 0 | 2.096 | 7.537 | 0.084 | 0.963 | 26.08 | 15.17 | 0.959 | 0.727 | 2.160 | 0 | 0.092 | 2.178 | 0.072 | 0 | -0.60 | 17.78 | 0.794 | 0.428 | -0.27 | 0.331 | 0.331 | 1.407 | 22.99 |
| 2016 | 4.870 | -7.93 | 0 | 1.386 | 0 | 1.517 | 7.701 | 0.141 | 0.735 | 20.02 | 12.45 | 0.756 | 0.528 | 17.74 | 0 | 0.324 | 1.920 | 0 | 0 | -1.4 | 12.06 | -0.17 | 0.433 | 0.416 | 0.250 | 0.250 | 0.697 | 25.22 |
| 2017 | -0.56 | 4.232 | -0.07 | -0.51 | 0 | -0.49 | -1.39 | 0 | -0.18 | -2.83 | 6.561 | -0.22 | -0.09 | -0.36 | 0 | 0.132 | -0.31 | 0 | 0 | 2.910 | -2.98 | -0.07 | -0.08 | -0.1 | -0.05 | -0.05 | -0.18 | -3.24 |
| 2018 | 2.868 | -5.68 | 0.200 | 1.23 | 0 | 1.370 | 2.879 | 0 | 0.711 | 19.47 | 40.64 | 0.587 | 0.211 | 1.411 | 0 | -0.06 | 1.538 | 0 | 0 | 0.357 | 10.57 | 0.494 | 0.304 | 0.324 | 0.210 | 0.210 | 0.567 | 19.52 |

Source: UN Comtrade: Coding system HS 130231 Agar-agar.

**Figure 5.** International sector specialization dynamics “Agar agar”, in the Membar countries; Lafay index [1].




| | AT | BE | BG | HR | CY | CZ | DK | EE | FI | FR | DE | GR | HU | IE | IT | LV | LT | LU | MT | NL | PL | PT | RO | SK | SI | ES | SE | GB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | -0.60 | 1.609 | -0.09 | -0.11 | -0.02 | -0.63 | -5.17 | 0.069 | -0.07 | 10.59 | 1.281 | -0.38 | -0.25 | -0.25 | -1.42 | -0.02 | -0.05 | 0 | -0.07 | -0.03 | -2.64 | -0.14 | -0.32 | -0.36 | -0.06 | -3.79 | -0.30 | 3.300 |
| 2013 | -0.69 | 1.569 | -0.09 | -0.12 | -0.01 | -0.62 | -5.29 | 0.125 | -0.07 | 10.88 | 1.554 | -0.21 | -0.23 | -0.40 | -0.03 | -0.06 | -0.05 | 0 | -0.12 | 0.080 | -2.25 | -0.16 | -0.32 | -0.49 | -0.03 | -3.80 | -0.88 | 1.810 |
| 2014 | -0.76 | 2.672 | -0.06 | -0.12 | -0.01 | -0.64 | -5.44 | 0.197 | -0.08 | 10.87 | 1.078 | -0.23 | -0.32 | -0.45 | -0.20 | -0.04 | -0.06 | 0 | -0.10 | 0.795 | -2.06 | -0.09 | -0.37 | -0.40 | -0.02 | -4.44 | -0.88 | 1.240 |
| 2015 | -0.62 | 1.930 | -0.04 | -0.08 | -0.00 | -0.54 | -5.66 | 0.208 | -0.07 | 10.13 | 3.615 | -0.19 | -0.25 | -0.59 | -0.36 | -0.03 | -0.04 | 0 | -0.09 | -0.11 | -1.70 | -0.08 | -0.27 | -0.29 | -0.02 | -4.89 | -1.39 | 1.511 |
| 2016 | -0.72 | 2.182 | -0.03 | -0.12 | -0.01 | -0.59 | -5.36 | 0.164 | -0.08 | 10.97 | 3.108 | -0.21 | -0.37 | -0.77 | -0.29 | -0.02 | -0.06 | 0 | -0.05 | -0.73 | -1.6 | -0.10 | -0.21 | -0.29 | -0.03 | -5.80 | -1.09 | 2.183 |
| 2017 | -0.73 | 1.586 | -0.03 | -0.11 | -0.01 | -0.78 | -4.98 | 0.073 | -0.11 | 11.40 | 3.273 | -0.28 | -0.36 | -1.07 | -0.71 | -0.07 | 0.005 | 0 | 0 | -0.81 | -1.57 | -0.11 | -0.31 | -0.25 | -0.07 | -6.15 | -0.18 | 2.430 |
| 2018 | -0.60 | 2.238 | -0.04 | -0.11 | -0.01 | -0.50 | -5.14 | 0.023 | -0.11 | 11.23 | 3.512 | -0.24 | -0.33 | -0.91 | -0.39 | -0.08 | -0.01 | 0 | -0.10 | -0.84 | -2.44 | -0.13 | -0.39 | -0.25 | -0.06 | -7.34 | -0.22 | 3.333 |

Souce: UN Comtrade: Coding system HS 130239.

**Figure 6.** International sector specialization dynamics “Carrageenan”, in the Membar countries; Lafay index [1].

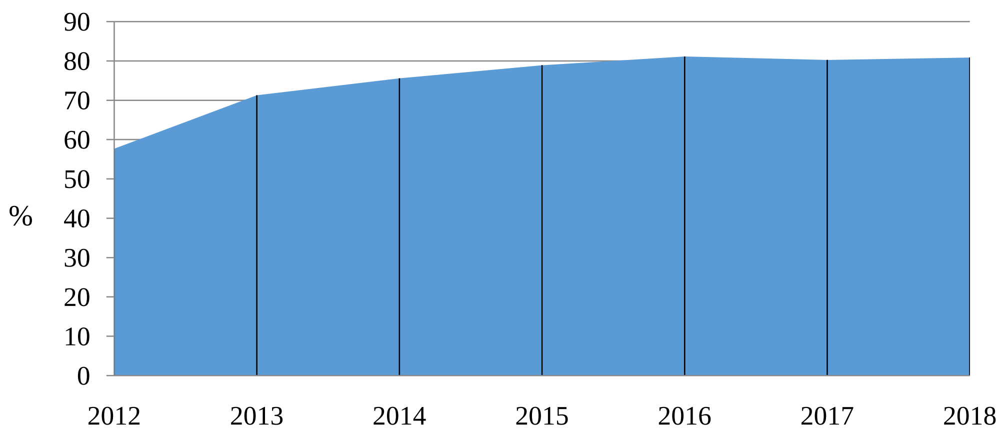
For agar agar, Table 3 itself indicates annual growth rates based on virtuous business circumstances in the largest number of EU countries. For carrageenan, on the other hand, the annual growth rates for carrageenan are less lively. This is not a favourable condition for production processes that optimist the use of this semi-finished product.

The trends in the annual growth rates of the Economic trade balance index show the same trend as the previous index on the quantities of trade. However, the different economic situations play a certain role in the changes that have occurred, due to the different geographical origins of the products examined. The world market trend also influences the price levels of semi−finished products produced in the European Union.

With regard to the measurement of the circular economy, Circularity Index referring to the European Union, in the time horizon 2012–2018, shows a lively production sector, the production of agar agar and carrageenan enters the circuit in the quality of second raw material in the production of food for increasing rates (Figure 7). Instead, the Circularity Index indicator shows different levels of utilization of these algal semi−finished products by observing individual EU member countries (Figure 8).

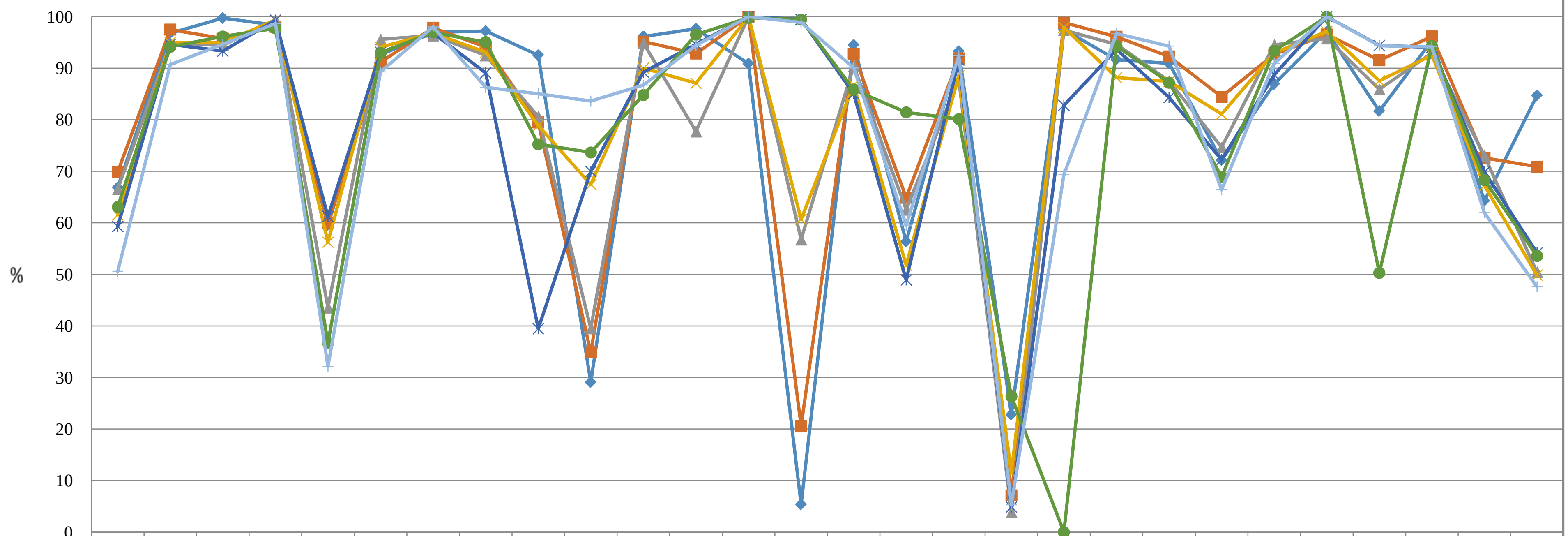
The Pricing incidence for agar agar (Figure 9) shows cheaper annual growth rates if the semi−finished product is purchased on the international market for use as a second raw material, rather than being product realized in the European Union from the use of FHC. For carrageenan, in most EU Member States, most of the Pricing incidences are negative (Figure 10). Therefore, the economic convenience is from the market.

Finally, Figure 11 allows formulating hypotheses of growth of algae imports, and less active hypotheses in correspondence of the export of algae of the European Union's crops origin. This would highlight food uses of algae FHC in their natural state on the EU. At the same time, it testifies to the industrial transformation of the natural origin algae FHC, which is quite dynamic. This increasingly pushes, on the one hand, towards climate security respect, on the other hand, to accelerate the so-called circularity rate of the economy of the countries of the European Union. Moreover, it cannot escape careful observation that most algae are subjected to journeys of hundreds, or rather thousands, of kilometers.




Source: UN Comtrade.

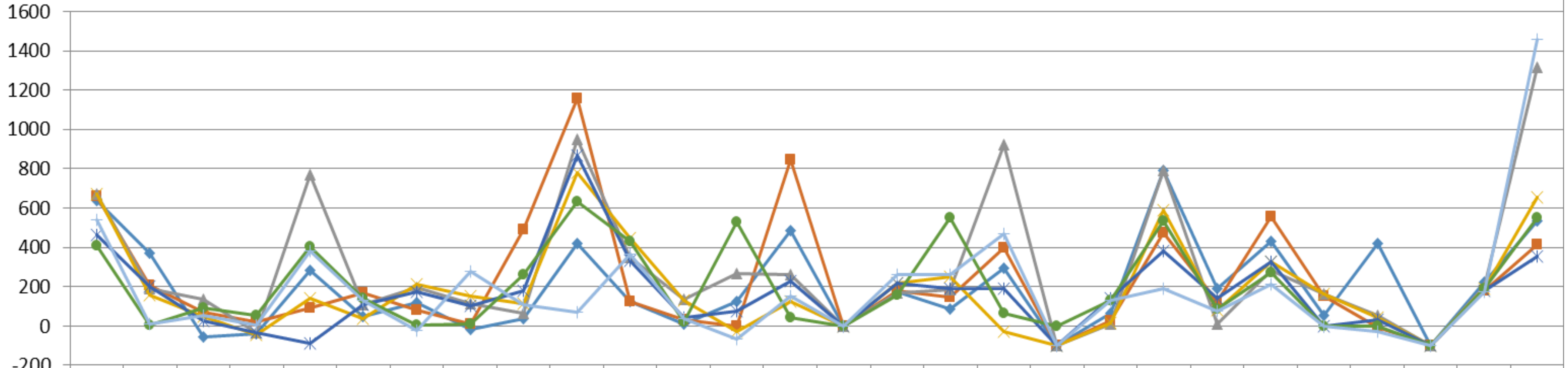
**Figure 7.** Increasing evolutionary trend of the percentage values of the Circularity index due to the virtuous industrial use of “second raw material” in the EU.




| | AT | BE | BG | HR | CY | CZ | DK | EE | FI | FR | DE | GR | HU | IE | IT | LV | LT | LU | MT | NL | PL | PT | RO | SK | SI | ES | SE | GB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | 66.87 | 96.76 | 99.72 | 98.34 | 59.58 | 92.58 | 96.95 | 97.19 | 92.51 | 29.07 | 96.13 | 97.64 | 90.86 | 5.349 | 94.51 | 56.34 | 93.29 | 22.78 | 97.5 | 91.64 | 90.92 | 72.15 | 86.90 | 97.09 | 81.67 | 95.36 | 64.23 | 84.70 |
| 2013 | 69.87 | 97.5 | 95.75 | 98.03 | 59.92 | 91.17 | 97.82 | 94.13 | 79.47 | 34.87 | 95.16 | 92.84 | 100 | 20.59 | 92.84 | 64.88 | 91.87 | 7.157 | 98.83 | 96.08 | 92.26 | 84.46 | 92.69 | 96.55 | 91.55 | 96.13 | 72.59 | 70.90 |
| 2014 | 66.55 | 94.81 | 94.43 | 99.4 | 43.56 | 95.59 | 96.34 | 92.48 | 80.62 | 39.54 | 94.91 | 77.73 | 100 | 56.77 | 90.45 | 62.56 | 87.87 | 3.877 | 97.38 | 94.60 | 87.50 | 74.65 | 94.52 | 95.76 | 85.88 | 92.94 | 72.99 | 50.43 |
| 2015 | 61.54 | 94.99 | 94.99 | 99.31 | 56.25 | 94.06 | 96.79 | 93.09 | 78.84 | 67.43 | 90.00 | 87.09 | 99.99 | 60.69 | 86.75 | 51.79 | 88.48 | 11.46 | 97.90 | 88.16 | 87.42 | 81.09 | 92.93 | 97.12 | 87.55 | 92.54 | 67.24 | 49.83 |
| 2016 | 59.29 | 94.62 | 93.31 | 99.31 | 61.22 | 93.05 | 96.82 | 89.06 | 39.46 | 69.99 | 89.21 | 94.62 | 99.99 | 99.47 | 85.05 | 48.92 | 91.57 | 4.873 | 82.79 | 93.63 | 84.31 | 72.24 | 88.69 | 100 | 94.41 | 94.04 | 69.88 | 54.19 |
| 2017 | 63.09 | 94.14 | 96.15 | 97.72 | 36.69 | 92.96 | 96.95 | 95.03 | 75.24 | 73.65 | 84.78 | 96.50 | 99.78 | 99.44 | 85.83 | 81.44 | 80.12 | 26.34 | 0 | 94.29 | 87.19 | 68.91 | 93.35 | 100 | 50.27 | 94.31 | 68.28 | 53.56 |
| 2018 | 50.57 | 90.69 | 94.66 | 98.65 | 32.13 | 89.28 | 98.01 | 86.27 | 85.04 | 83.62 | 86.72 | 94.41 | 99.98 | 98.85 | 90.05 | 59.53 | 92.42 | 5.313 | 69.36 | 96.73 | 94.27 | 66.40 | 90.92 | 100 | 94.36 | 94.15 | 61.96 | 47.60 |

Source: UN Comtrade.

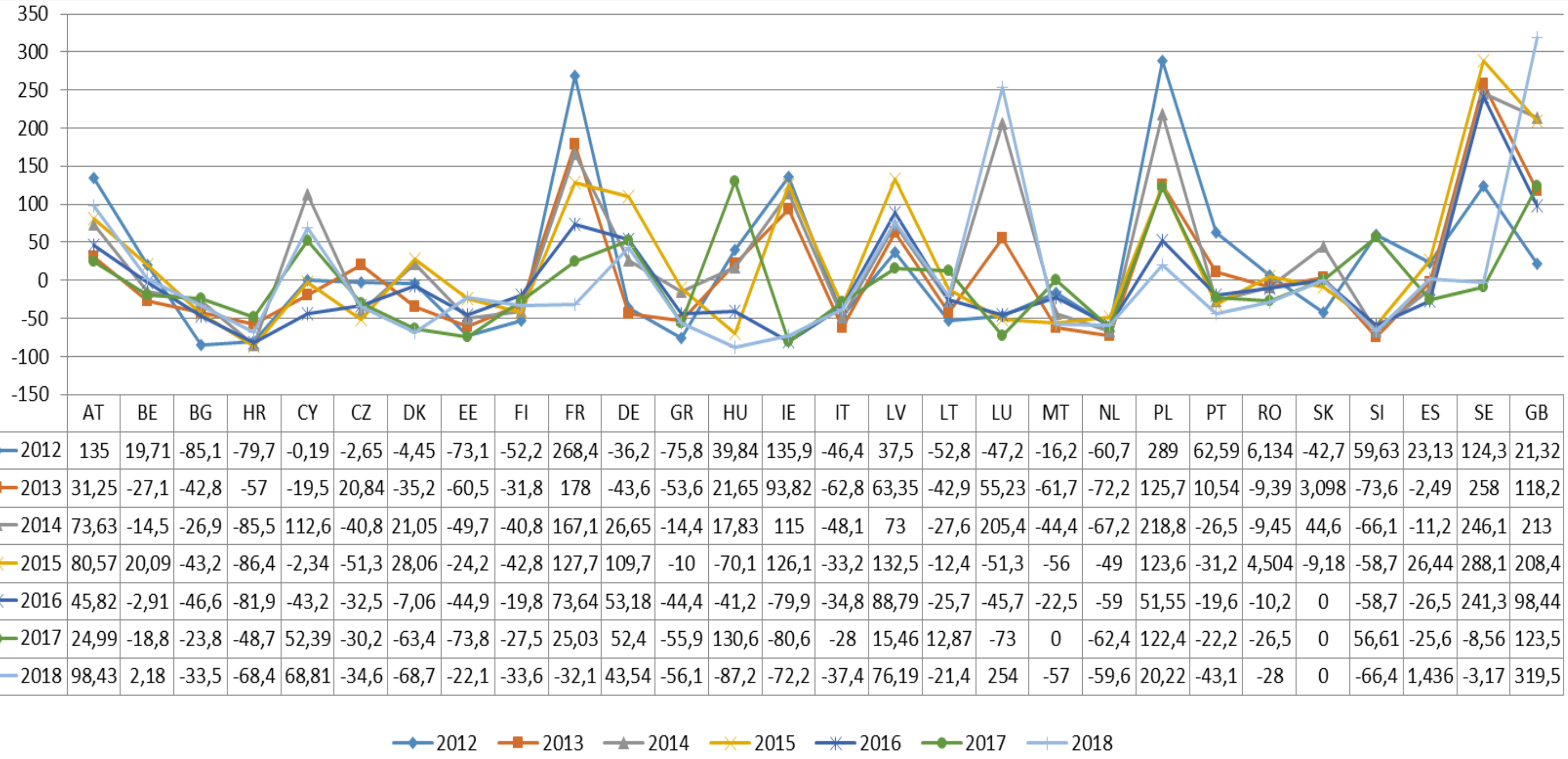
**Figure 8.** Different levels of the evolutionary trend of the percentage values of the Circularity index of the "second raw material" in the Member Countries of the European Union. [2].




| | AT | BE | BG | HR | CY | CZ | DK | EE | FI | FR | DE | GR | HU | IE | IT | LV | LT | LU | MT | NL | PL | PT | RO | SK | SI | ES | SE | GB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | 637 | 373 | -57 | -41 | 284 | 50,2 | 121 | -15 | 37,6 | 419 | 127 | 9,2 | 123 | 483 | 0 | 175 | 85,4 | 295 | -100 | 62,2 | 793 | 191 | 431 | 53,8 | 419 | -98 | 226 | 535 |
| 2013 | 662 | 208 | 71,5 | 20 | 93 | 167 | 78,8 | 10,6 | 493 | 1158 | 127 | 30,8 | 0 | 844 | 0 | 181 | 145 | 399 | -100 | 28,3 | 473 | 127 | 557 | 154 | -8,6 | -99 | 179 | 412 |
| 2014 | 673 | 188 | 138 | -34 | 772 | 110 | 198 | 113 | 62,6 | 949 | 347 | 135 | 268 | 262 | 0 | 168 | 184 | 921 | -100 | 9,82 | 789 | 11,6 | 282 | 164 | 53,9 | -99 | 201 | 1315 |
| 2015 | 673 | 156 | 50,1 | -43 | 143 | 39,2 | 214 | 155 | 117 | 783 | 450 | 128 | -26 | 124 | 0 | 219 | 252 | -29 | -100 | 14,7 | 587 | 79,5 | 328 | 162 | 43,2 | -98 | 189 | 655 |
| 2016 | 463 | 201 | 25,4 | -35 | -89 | 109 | 176 | 102 | 177 | 866 | 335 | 43,8 | 73,1 | 229 | 0 | 216 | 190 | 190 | -100 | 139 | 380 | 142 | 329 | 0 | 31 | -99 | 179 | 355 |
| 2017 | 410 | 2,83 | 93,8 | 56,1 | 404 | 139 | 4,93 | 9,89 | 261 | 632 | 433 | 20,8 | 529 | 43,4 | 0 | 159 | 553 | 67 | 0 | 133 | 537 | 86,9 | 271 | 0 | 0 | -99 | 192 | 550 |
| 2018 | 539 | 12 | 52,7 | 5,26 | 380 | 131 | -21 | 279 | 110 | 70,6 | 366 | 40,1 | -66 | 155 | 0 | 261 | 264 | 468 | -100 | 129 | 189 | 78 | 213 | 0 | -26 | -99 | 175 | 1459 |

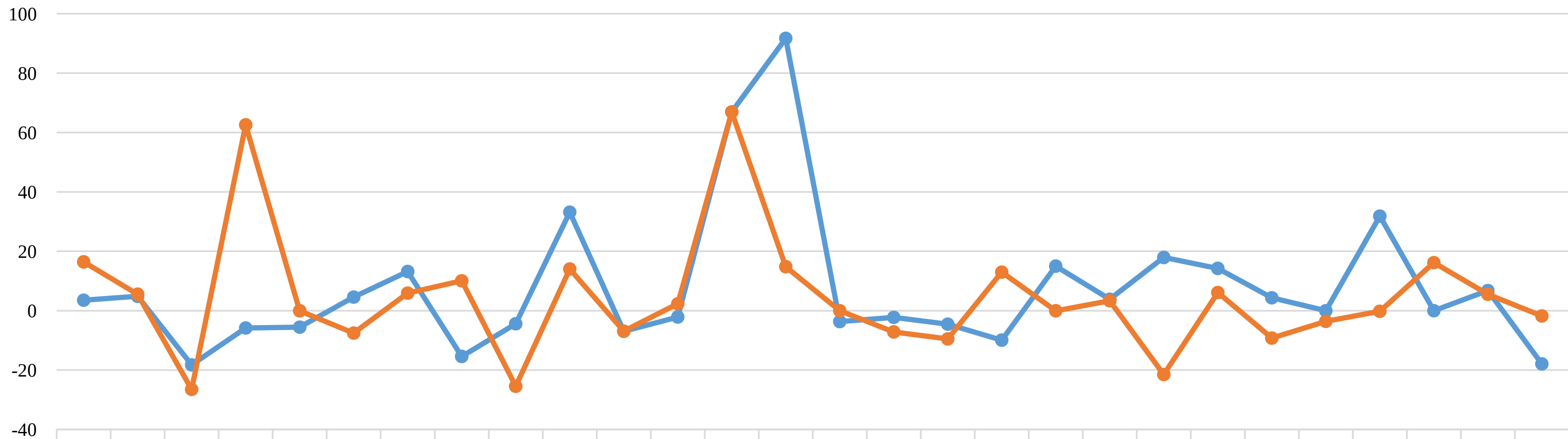
2012 2013 2014 2015 2016 2017 2018

**Figure 9.** Dynamic projection of average prices “Agar Agar” Member countries [3].




| | AT | BE | BG | HR | CY | CZ | DK | EE | FI | FR | DE | GR | HU | IE | IT | LV | LT | LU | MT | NL | PL | PT | RO | SK | SI | ES | SE | GB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | 135 | 19,71 | -85,1 | -79,7 | -0,19 | -2,65 | -4,45 | -73,1 | -52,2 | 268,4 | -36,2 | -75,8 | 39,84 | 135,9 | -46,4 | 37,5 | -52,8 | -47,2 | -16,2 | -60,7 | 289 | 62,59 | 6,134 | -42,7 | 59,63 | 23,13 | 124,3 | 21,32 |
| 2013 | 31,25 | -27,1 | -42,8 | -57 | -19,5 | 20,84 | -35,2 | -60,5 | -31,8 | 178 | -43,6 | -53,6 | 21,65 | 93,82 | -62,8 | 63,35 | -42,9 | 55,23 | -61,7 | -72,2 | 125,7 | 10,54 | -9,39 | 3,098 | -73,6 | -2,49 | 258 | 118,2 |
| 2014 | 73,63 | -14,5 | -26,9 | -85,5 | 112,6 | -40,8 | 21,05 | -49,7 | -40,8 | 167,1 | 26,65 | -14,4 | 17,83 | 115 | -48,1 | 73 | -27,6 | 205,4 | -44,4 | -67,2 | 218,8 | -26,5 | -9,45 | 44,6 | -66,1 | -11,2 | 246,1 | 213 |
| 2015 | 80,57 | 20,09 | -43,2 | -86,4 | -2,34 | -51,3 | 28,06 | -24,2 | -42,8 | 127,7 | 109,7 | -10 | -70,1 | 126,1 | -33,2 | 132,5 | -12,4 | -51,3 | -56 | -49 | 123,6 | -31,2 | 4,504 | -9,18 | -58,7 | 26,44 | 288,1 | 208,4 |
| 2016 | 45,82 | -2,91 | -46,6 | -81,9 | -43,2 | -32,5 | -7,06 | -44,9 | -19,8 | 73,64 | 53,18 | -44,4 | -41,2 | -79,9 | -34,8 | 88,79 | -25,7 | -45,7 | -22,5 | -59 | 51,55 | -19,6 | -10,2 | 0 | -58,7 | -26,5 | 241,3 | 98,44 |
| 2017 | 24,99 | -18,8 | -23,8 | -48,7 | 52,39 | -30,2 | -63,4 | -73,8 | -27,5 | 25,03 | 52,4 | -55,9 | 130,6 | -80,6 | -28 | 15,46 | 12,87 | -73 | 0 | -62,4 | 122,4 | -22,2 | -26,5 | 0 | 56,61 | -25,6 | -8,56 | 123,5 |
| 2018 | 98,43 | 2,18 | -33,5 | -68,4 | 68,81 | -34,6 | -68,7 | -22,1 | -33,6 | -32,1 | 43,54 | -56,1 | -87,2 | -72,2 | -37,4 | 76,19 | -21,4 | 254 | -57 | -59,6 | 20,22 | -43,1 | -28 | 0 | -66,4 | 1,436 | -3,17 | 319,5 |

**Figure 10.** Dynamic projection of average prices “Carrageninan” Member countries [3].




| | AT | BE | BG | HR | CY | CZ | DK | EE | FI | FR | DE | GR | HU | IE | IT | LV | LT | LU | MT | NL | PL | PT | RO | SK | SI | ES | SE | GB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Import | 3.546 | 4.855 | -18.2 | -5.83 | -5.54 | 4.585 | 13.20 | -15.4 | -4.38 | 33.20 | -6.91 | -2.12 | 66.94 | 91.73 | -3.64 | -2.23 | -4.52 | -9.91 | 15.01 | 3.870 | 17.93 | 14.25 | 4.351 | 0 | 31.84 | 0 | 6.768 | -17.9 |
| Export | 16.46 | 5.585 | -26.4 | 62.58 | 0 | -7.52 | 5.933 | 10.11 | -25.4 | 14.05 | -6.84 | 2.372 | 66.94 | 14.84 | 0.032 | -7.12 | -9.48 | 13.01 | 0 | 3.369 | -21.4 | 6.135 | -9.18 | -3.54 | -0.16 | 16.20 | 5.573 | -1.75 |

**Figure 11**. Average annual growth rate “Seaweed fit for human consumption” sector ( HS 121221), in the seven−year period 2012–2018 [4].

## 4. Conclusions

In essence, as can be seen from the comparison of indicators to measure the circularity of algal products, the food industry in the European Union is lively. This encourages innovations in food processes aimed at the production of new products that periodically update the list of Novel foods. The list novel food compiles all the authorized novel food in the European Union to date Commission Regulation (EU) 2019/1272 of 29 July 2019 correcting implementing Regulation (EU) 2017/2470 establishing the Union list of novel food.

The more production processes are able to develop technological innovations in resource efficiency; the more the transition to a circular economy is facilitated. The new food products examined in our study contribute to creating innovative and more efficient business opportunities and production methods as well as creating new opportunities for employment, integration and social cohesion that save energy.

Although further research is needed in the future, our study has highlighted the progressive cultural and structural change needed in the transition to a circular economy that respects food security and health consumers [27].

The support of an effective regulatory apparatus in terms of circular economy, lean and stimulating for economic operators, could liven up the current trend towards the aforementioned change. In fact, common measurability criteria of the circular economic make expectations more effective eco sustainable.

Faced with the sustainable economic, social and environmental effects that the algal sector has developed in the economic systems analysed in our study, it seems essential that the measurability of macro circularity should be complementary to the micro circularity. The measurability of circularity at the micro level is required in a context where natural algal resources are use in a range of industrial alternatives and not only for food production. Consequently, it is necessary to strengthen the analysis of enterprises in order to have a point of convergence on the commercial strategies adopted and to encourage a reciprocal exchange of results. The microanalysis is important for the final circularity of resources, thus minimizing waste and the possibility of recycling waste that can be generate by algal processing activities. Instead, the measurability at the macro level of international trade can provide elements able to quantify the level of physical and economic movements and give the measure of the business that can develop in the EU with the possible environmental consequences that may result.

Finally, the support of an effective regulatory framework on the circular economy could streamline procedures and stimulate economic operators in the virtuous direction of economic production activities, reviving the current trend of change. Common criteria for measuring the circular economy would make eco-sustainable expectations more effective.

## Conflict of interest

All authors declare no conflict of interest in this paper.

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