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CHANGES IN FOOD WASTE LEVEL IN THE EU COUNTRIES

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ABSTRACT

Food waste is the world-wide social and economic problem, and also large and unnecessary burden for the environment. In this paper was taken the problem of comparing changes in the level of food wastage in the EU countries in 2000–2011. There were used two techniques: multidimensional comparative analysis (MCA) and grade data analysis (GDA). The second one is used for the first time in this type of issues. Based on these techniques there were built synthetic indicators, which were used as a criterion for classification of EU countries in terms of the pace of reducing the level of food waste. It appears that usage of different techniques to construction of indicators gave a divergent arrangements.

Key words: multidimensional comparative analysis, grade data analysis, synthetic index, classification of objects, food waste

INTRODUCTION

Wasting food is not just a world-wide social problem. It is also an important economic problem and a large and unnecessary burden for the environment. Typically, the wasted food product should be associated not only with the superfluous production, but also with used packaging, transport, energy and the emission of industrial waste or additional greenhouse gases which have a close relationship with decaying, wasted food.

As a result – as the Federation of Polish Food Banks alerts (http://www.ekologia.pl) – discarded food is equivalent to wasting gallons of water and energy used for its production, transport, storage and preparation. To illustrate the problem in more details, the Federation of Polish Food Banks cites the following examples: "a sandwich with cheese thrown into the trash is equal to as much as 90 litres of wasted water, while a kilogram of potatoes is up to 300 litres, and is better not to talk about beef meat, because to produce one kilogram of beef takes between 5 and 10,000 litres of water. Additionally, food production also requires energy in the form of fuel and electricity. 10 calories of fuel is required to produce 1 kcal of food. As a result of wasted food alone, Europeans emitted 170 million tons of carbon dioxide, as much as the whole of the Netherlands or Venezuela emit per year – estimates the FPFB. Methane coming from decaying food is a 20 times more dangerous greenhouse gas than carbon dioxide" – alarms Marek Borowski, President of the Federation of Polish Food Banks.

According to the European Commission, calculations in Europe in the XXI century about 90 million t of food is wasted annually [European Environment Agency 2012]. It should be emphasized that food is wasted at every stage of the food chain – 'from farm to fork', meaning that wasting food also concerns producers, processors, retailers and restaurateurs. More information on this can be found eg. in the European Commis-

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sion Report 054 (2010). The FAO (Food And Agriculture Organization Of The United Nations) provides information about food waste in plant and animal production.

The aim of this study is to rank EU countries by effectiveness in reducing the level of food wastage in the main part of the production chain – sale. Therefore, the data does not include losses related to, for example plant production that occurred before and during harvesting and food waste by consumers. An additional objective is to identify the problems connected with unambiguity of such order, which depends on employed technique of the synthetic index construction.

Methods and research tools used in this paper are chosen techniques derived from a wide collection known as multidimensional comparative analysis – MCA [Kukuła 2000] and instruments from grade data analysis – GDA [Ciok et al. 1995, Szczesny 2002, Kowalczyk et al. 2004].

MATERIAL AND METHODS

Currently, it is virtually impossible to collect detailed, long term, uniform data for the EU countries (especially for those countries that joined EU after 2000). For this reason, for the research was used information about the waste of food crops and livestock production in the European Union countries covering the period 2000–2011 and collected by FAO (http://faostat3.fao.org/home). Unfortunately, the data for subsequent periods related to the same methodology, are not available yet. This selection has also decided about reduction to the analysis of several variables describing the waste in a fairly broad groups of products. For the category of waste in plant production in the paper, the following were analyzed in terms of aggregated data in tons: X_1 – cereals (except beers), X_2 – fruits (except wine), X_3 – oil crops and legumes, X_4 – the roots of starch (including potatoes) and X_5 – vegetables. The category of waste in animal production (also in tonnes) consisted of: X_6 – animal fats, eggs, meat, offal, X_7 – milk (excluding butter).

Changes of the level of food wastage in the individual countries for the studied period can be assessed in different ways. Most methods offered by multivariate data analysis use the synthetic index which takes into account the levels of waste in the individual groups of product per capita. In addition, to reduce the sensitivity of the assessment due to the weather conditions and the associated quality of raw material, the mean values are usually compared for several years. The study covers the period 2000 to 2011, and for comparison, the average of three adjacent years were used for each variable. This allowed for the four values of the synthetic index assessing the value of waste to be obtained for each three-year periods. The difference in the value of the synthetic index for the first and last three years was assumed as one of the two ratings of changes in the level of food wastage in this period. In the case of data from the years 2000–2011 a maximum mean values for six contiguous years could be applied. The methodology of construction of the synthetic indices – used to organize the objects described by many variables – is widely known and has been mentioned in many publications, also in Polish language [Strahl 1978, Strahl 1985, Zeliaś 2000, Panek 2009, Kukuła 2014, Kukuła and Luty 2015]. For this reason this methodology will not be discussed more widely. Most of the classical techniques of construction of the synthetic indices requires normalized data. In the paper was chosen the unitarisation zeroed method, because it transforms the value of each variable to the interval [0; 1] which allows for relatively easy intuitive assessment of countries in each category. More about the advantages of this normalization technique can be found in Kukuła [2000].

However, by relying only on the difference of the classical synthetic indices, even if mean values from a selected number of years are used, there is always discussion whether the average should cover three, four or six years. It seems that before making the choice of the synthetic index it should first be considered which properties should have such an indicator. On the other hand, in cases of data yearly disposal, it would be good to use an indicator that directly uses all the data from the whole period and is not too sensitive to fluctuations between adjacent years. For this purpose, basic tools of the instruments of grade correspondence analysis

(GCA) can be used. In this paper this technique of building rankings has been used because have pointed out the efficiency in many applications, but is still relatively little known in the literature. More about the GCA can be read in papers e.g. [Szczesny 2002, Kowalczyk et al. 2004, Koszela 2016].

One of the main measuring GCA-based methods that has been used in this work is the ar (area) marker for measuring the variation of two structures. To introduce the method of the meter construction and its basic properties, having two structures, it is supposed that:

$$\mathbf{x} = (x_1, \ldots, x_n),\ \mathbf{y} = (y_1, \ldots, y_n) \in \Re_+^n : x_i, y_i \geq 0,\ \sum_{i=1}^{n} x_i = \sum_{i=1}^{n} y_i = 1$$

Based on them a polygonal curve $L_{[\mathbf{x},\mathbf{y}]}$ can be determined (in a two-dimensional coordinate system), which is determined by n + 1 points:

$$P_0 = (0; 0),\ P_j = (x_j^\wedge, y_j^\wedge),\ j = 1,\ 2,\ \ldots,\ n$$

where: $x_j^\wedge := \sum_{i=1}^{j} x_i,\ y_j^\wedge := \sum_{i=1}^{j} y_i$

and obviously:

$P_n = (1; 1)$

where: $x_n^\wedge = \sum_{i=1}^{n} x_i = 1,\ y_n^\wedge = \sum_{i=1}^{n} y_i = 1$

The curve $L_{[\mathbf{x},\mathbf{y}]}$ defines clearly, some decreasing, partly linear function $C_{[\mathbf{y}:\mathbf{x}]}(t)$, which maps each closed interval [0; 1]. This function is used to determine the differentiation measures of two considered, ordered structures **x** i **y**:

$$\mathrm{ar}(\mathbf{y} : \mathbf{x}) = \mathrm{ar}\left(C_{[\mathbf{y}:\mathbf{x}]}\right) = 1 - 2\int_0^1 C_{[\mathbf{y}:\mathbf{x}]}(t)\,\mathrm{d}t \qquad (1)$$

From the formula (1) can be concluded that index ar takes values from the interval [–1, 1] and $\mathrm{ar}(\mathbf{y} : \mathbf{x}) = -\mathrm{ar}(\mathbf{x} : \mathbf{y})$. More about this indicator is explained in e.g. [Szczesny 2002, Szczesny et al. 2012, Binderman et al. 2014].

In order to indicate the interesting property of the constructed index we consider a simplified example. Let's suppose that the sequence A = (o_1, …o_i, …, o_{2m}) represents the wasted food in consecutive *2m* years in a country A. *n* o_i = 1/(2 m) for *i* = 1, …, 2m, which will be modified in such a way to get a serie of –B_i = (o_1, … o_i + *e*, …, o_{2m}) for chosen $1 \leq i \leq 2m$ and $e > 0$. In this case it is easy to show that if the series A and B_i respectively will be changed into the structure of **x** and $\mathbf{y}_i$, then $\mathrm{ar}(\mathbf{y}_i : \mathbf{x})$ takes positive values when the $(m + 1) \leq i \leq 2m$ and negative values when $1 \leq i \leq m$ and value $|\mathrm{ar}(\mathbf{y}_i : \mathbf{x})|$ increases with an increase in |*m* – i|. Therefore value $\mathrm{ar}(\mathbf{y}_i : \mathbf{x})$ increases with an increase of *i* = 1, …, 2*m*. This direction of changes in $\mathrm{ar}(\mathbf{y}_i : \mathbf{x})$ values is actual for any sequence (o_1, … o_i, …, o_{2m}). It seems to be a useful property. For this reason, it seems natural to use this indicator for the ordering the EU countries in terms of changes in the level of food waste. Index with similar properties can be obtained using the difference between the weighted average of the two parts of period *2m* years for the tested product group if the used weights will be decreasing with increasing *i* = 1, …, *m* and increasing with an increase of *i* = *m* + 1, …, 2*m*.

In the methods associated with GCA, an important role is played by the over-representation map, which is used to create a visualization of the analyzed data. To explain this concept, let's assume that the data collected on the diagnostic value of the variable for each country during the *k*-years form a matrix:

$$\mathbf{X} = \begin{bmatrix} x_{1,1} & x_{1,2} & \cdots & x_{1,k} \\ x_{2,1} & x_{2,2} & \cdots & x_{2,k} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n,1} & x_{n,2} & \cdots & x_{n,k} \end{bmatrix} = \left[x_{i,j} \right],\ i = 1,\ \ldots,\ n,\ j = 1,\ \ldots,\ k \qquad (2)$$

where: n – number of objects (countries),
k – number of years in the analyzed period,
$x_{i,j}$ is the value of a variable on the object O_i in the year numbered k.

The graphical form of the over-representation map (Fig. 1) is a unit square [0; 1] × [0; 1]. The square is divided by vertical and horizontal lines of rectangles filled with the shades of gray, which correspond to the values calculated according to the formula (2):

$$h_{i,j} = \frac{\frac{x_{i,j}}{x_{+,+}}}{\frac{x_{i,+}}{x_{+,+}}\frac{x_{+,j}}{x_{+,+}}} = \frac{\frac{x_{i,j}}{x_{+,j}}}{\frac{x_{i,+}}{x_{+,+}}} = \frac{\frac{x_{i,j}}{x_{i,+}}}{\frac{x_{+,j}}{x_{+,+}}} \quad \text{where } i = 1, ..., n, j = 1, ..., k \qquad (3)$$

$$x_{i,+} = \sum_{j=1}^{k} x_{i,j},\ \ x_{+,j} = \sum_{i=1}^{n} x_{i,j}, x_{+,+} = \sum_{i=1}^{n}\sum_{j=1}^{k} x_{i,j}$$

Vertical lines are routed in points: $0, \frac{x_{+,1}}{x_{+,+}}, \ldots, \sum_{i=1}^{j} \frac{x_{+,i}}{x_{+,+}}, \ldots, 1$, and the horizontal lines at points $0, \frac{x_{1,+}}{x_{+,+}}, \ldots, 1$. Figure 1 shows the map illustrating the structure of the waste of food of plant origin. Countries have been organized using ar measures. The width of the horizontal stripes show the share of wasted food of plant origin in the 28 countries during the period 2000–2011. A particularly large share are occupied by Poland, Germany and France. While the width of the vertical strips depict the temporal structure of the waste products of plant origin. Grayscale indicates the quotients values of the individual components of the time structure for each country to the corresponding structure components of the entire series (horizontal structures), and the quotients values of the individual structure components of 28 EU countries in a given year to the corresponding components of the structure of these countries, calculated for the entire period of 12 years. From Figure 1 we can conclude that out of 28 countries, Poland and Lithuania are distinguished by the fact that their time structure (horizontal) of wasted food value in relation to the time structure of the entire series shows a significant improvement in reducing waste (dark rectangles in 2000–2002 and bright in 2009–2011), while in the case of Hungary, the Netherlands and France, the situation is unfavorable. By interpreting the graphic differently (vertical structure), it can be observed that the share of wasted food in Lithuania and Poland, out of the wasted food in all 28 countries in 2000 and 2001 is significantly higher than that in the entire period of 12 years, while in each of the years in the period 2008–2011 it is significantly smaller. In Figure 1 countries are arranged in order of $ar\left[\left(\frac{x_{i+1,1}}{x_{i+1,+}}, \ldots, \frac{x_{i+1,k}}{x_{i+1,+}}\right) : \left(\frac{x_{i,1}}{x_{i,+}}, \ldots, \frac{x_{i,k}}{x_{i,+}}\right)\right] \geq 0$ for $i = 1, \ldots, k - 1$. Therefore, it is ordered from the point of view of the country which, at that time received the biggest improvement in food waste of plant origin, to the country which has the worst results. This is the order generated by the ar index.

In this presentation of plant origin food wastage variable X was used, which is the sum (in tonnes) of waste for each product group. This is a highly simplified picture. To get a more precise view each aggregated group of products reported by FAO should be tested separately and a cumulative synthetic assessment should be made.

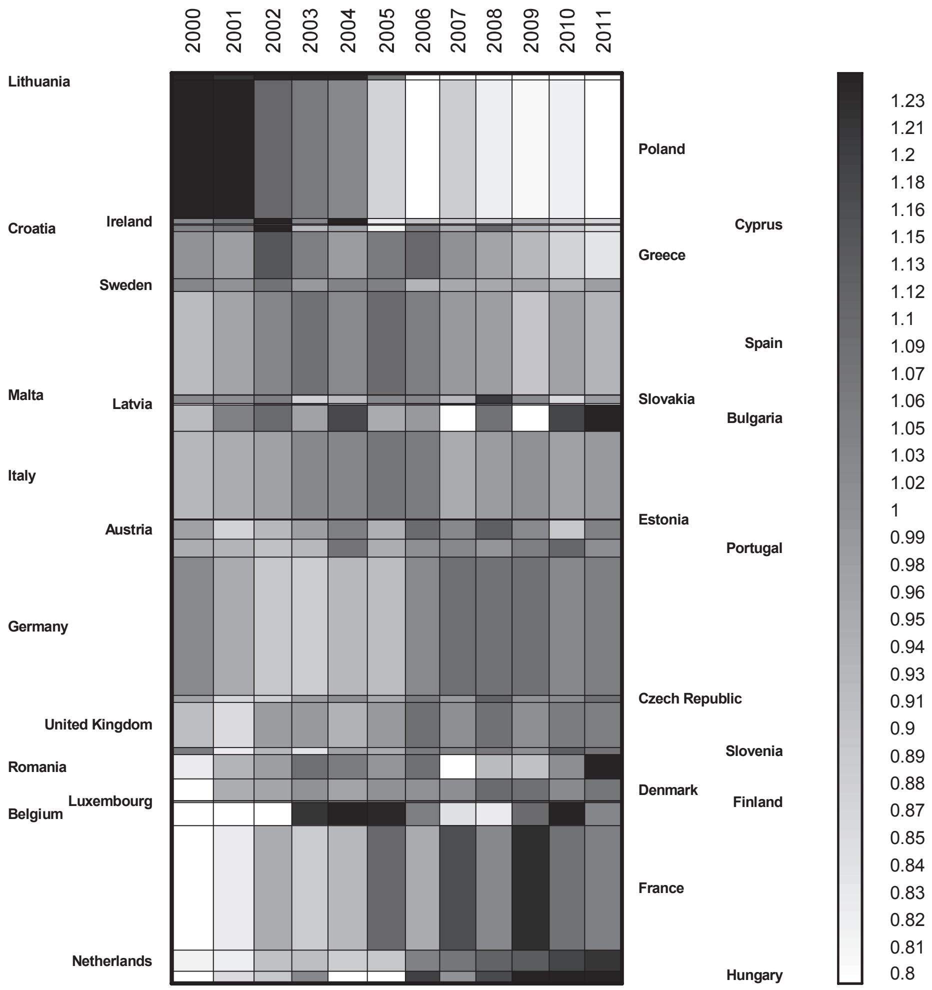

Fig. 1. Over-representation map showing the over-representation of the structure of the waste of plant products

Source: Own calculation based on FAO data.

For this purpose, it is necessary to not only have a well-sequence order but also evaluative indicator. Usage of *S* index is proposed, represented by the following formula:

$$S_i = \sum_{j=1}^{i} \frac{x_{j,+}}{x_{i,+}} \quad \text{for } i = 1, ..., n. \tag{4}$$

The graphics of these values correspond to the extremities of the intervals on the section [0; 1] defined by horizontal stripes of map over-representation. Therefore, the value uses information on both the order of the objects and the values for those objects in each row (width of the horizontal stripes). Note that if we were not interested in the size of the waste in each country, but only in the order of the waste structures in the consecutive years, each row of the matrix **X** prior to analysis should be divided by $x_{i,+}$ (then the over-representation map would have horizontal stripes of the same width). In this case the ratio *S* values will be i/n for $i = 1, …, n$. S_i, and values are, therefore ranks (item numbers) divided by *n*, the number of all objects.

RESULTS

To compare changes in the level of waste in different countries variables $Y_1, ..., Y_7$, were used, which were calculated by dividing the values of the variables $X_1, ..., X_7$ by the number of inhabitants of the country during each year of the tested period. The use of variables $Y_1, ..., Y_7$ also enables the comparison of the level of waste in different countries in the analyzed period. For this purpose, synthetic indices have been used widely used, which are defined as the mean value of the standardized sub-criteria. To reduce the impact of annual fluctuations to assess the changes, the analysis was performed in two variants;

- Variables U_i ($i = 1, ..., 7$) were created as the mean values of Y_i from 2000–2002 and variables V_i ($i = 1, ..., 7$) as the mean value of Y_i for the years 2009–2011, which, after standardization by zeroed unitarisation [Kukuła 2000, Kukuła and Luty 2015] were used to create synthetic indicators W_1 and W_2 as the mean values of standardized variables $U_1, ..., U_7$ and $V_1, ..., V_7$, the values of these indicators are presented in Table 1;
- Variables Z_i ($i = 1, ..., 7$) were created as the weighted mean values of Y_i from 2000–2005 with the following decreasing weights 0.208; 0.192; 0,175; 0.158; 0.142; 0.125 and variables T_i ($i = 1, ..., 7$) as the mean value of Y_i from 2006–2011 with the following increasing weights 0.125; 0.142; 0.158; 0,175; 0.192; 0.208, which, after normalization by zeroed unitarisation, were used to create synthetic indices W_3 and W_4 as the mean normalized values of the variables $Z_1, ..., Z_7$ and $T_1, ..., T_7$. The values of these indicators are presented in Table 1. Determining the weight was used a variant of individualization of the each year validity by assigning them points: 25, 23, 21, 19, 17 and 15 respectively (i.e. a point technique of creating weights in the personalized ranking), which after normalization have been rounded to three decimal places.

Table 1 also contains columns $R_1, ..., R_4$ containing the position of the country in the ranking of countries from those with the lowest level of waste to those with the highest level of waste (there are the ranks with values of $W_1, ..., W_4$). The last two columns (Gr_1 and Gr_2) contain information on the division of countries into four groups according to the thresholds for the indicators W_1 and W_2. As the thresholds was established: $\mu - \sigma, \mu, \mu + \sigma$, where the symbol μ is the mean value W_i, and σ symbol standard deviation W_i ($i = 1, 2$).

Table 1 shows that the lowest level of food waste, regardless of if indicators W_i, built on the basis of three- or six-years periods was noted in Finland and the United Kingdom of Great Britain and Northern Ireland (cf. values $W_1, ..., W_4$ and items in columns $R_1, ..., R_4$). Poland occupied one of the last places in the ranking in 2000–2002, ($R_1 = 26$), though has improved slightly, moving only about three places up in the period 2009–2011 ($R_2 = 23$). In the first period Poland is among the countries with the highest level of waste together with Cyprus and Greece ($Gr_1 = 4$), while in the second period (2009–2011) it is up to group 3 ($Gr_2 = 3$).

In order to build the ranking of countries due to the changes in food waste level, the following five indicators were used:

$$\xi_1 = W_2 - W_1,\ \xi_2 = W_4 - W_3,\ \xi_3 = W_2/W_1 - 1,\ \xi_4 = W_4/W_3 - 1,\ \xi_5 = (S_1 + \ldots + S_7)/7 \qquad (5)$$

where: S_i ($i = 1, 2, \ldots, 7$) – ratio defined by formula (4) for Y_i ($i = 1, 2, \ldots, 7$).

The calculated results are presented in Table 2. In a similar way to Table 1 in columns $R_1, ..., R_5$ shows ranking by reducing the level of waste and four groups of indicators, ξ_1 and ξ_5, were set up, using thresholds based on mean values and standard deviations of these indicators.

From Table 2 it can be concluded that the assessment of changes in the of waste level per capita is sensitive to the measurement method. There is a difference in this assessment when the change of the nominal waste level is considered (differences indicators assessing the level of waste in two extreme periods of three-years and two extreme periods of six-years respectively: ξ_1 and ξ_2) and different when changes take into account value for three-year periods (ξ_3), and six-year periods (ξ_4), or take into account annual changes over the entire 12 years (ξ_5). In the case of nominal changes in the level of food wastage in the analyzed period of time, the greatest progress in

Table 1. Indicators and rankings of food waste levels in 2000–2011 in the EU countries

	W_1	W_2	W_3	W_4	R_1	R_2	R_3	R_4	Gr_1	Gr_2
Austria	0,247	0,233	0,263	0,245	20	20	20	21	3	3
Belgium	0,143	0,299	0,201	0,300	10	25	16	25	2	4
Bulgaria	0,283	0,254	0,362	0,270	22	22	26	23	3	3
Croatia	0,205	0,125	0,215	0,139	18	7	17	8	3	2
Cyprus	0,521	0,349	0,547	0,371	28	27	28	27	4	4
Czech Republic	0,121	0,092	0,141	0,098	8	5	8	5	2	2
Denmark	0,289	0,287	0,313	0,288	24	24	23	24	3	4
Estonia	0,082	0,162	0,108	0,165	5	14	5	14	1	2
Finland	0,017	0,025	0,017	0,022	1	1	1	1	1	1
France	0,175	0,199	0,190	0,193	13	19	15	19	2	3
Germany	0,174	0,152	0,183	0,158	12	13	13	13	2	2
Greece	0,511	0,396	0,532	0,422	27	28	27	28	4	4
Hungary	0,177	0,143	0,172	0,149	15	11	10	10	2	2
Ireland	0,176	0,178	0,181	0,173	14	15	11	15	2	2
Italy	0,167	0,188	0,183	0,192	11	17	12	18	2	3
Latvia	0,068	0,063	0,084	0,075	3	3	4	3	1	1
Lithuania	0,186	0,145	0,225	0,151	16	12	19	11	2	2
Luxembourg	0,119	0,071	0,138	0,080	7	4	7	4	2	1
Malta	0,193	0,180	0,189	0,183	17	16	14	16	2	2
Netherlands	0,076	0,134	0,083	0,124	4	9	3	7	1	2
Poland	0,359	0,263	0,358	0,264	26	23	25	22	4	3
Portugal	0,271	0,193	0,271	0,187	21	18	21	17	3	3
Romania	0,136	0,134	0,165	0,139	9	10	9	9	2	2
Slovakia	0,209	0,129	0,221	0,155	19	8	18	12	3	2
Slovenia	0,298	0,328	0,304	0,331	25	26	22	26	3	4
Spain	0,284	0,235	0,313	0,242	23	21	24	20	3	3
Sweden	0,109	0,104	0,116	0,103	6	6	6	6	2	2
United Kingdom	0,062	0,062	0,063	0,061	2	2	2	2	1	1
Mean	0,202	0,183	0,219	0,189						
Standard deviation	0,119	0,091	0,123	0,094						

Source: Own calculation based on FAO data.

reducing the losses (both taking into account of three- and six-year periods) was recorded in countries that have wasted in the previous ranking the most food: Cyprus ($R_1 = 1$), Greece ($R_1 = 2$) and Poland ($R_1 = 3$). In comparison to the extreme three-year periods they belong to, they are the group of countries with the largest decrease in the nominal level of wasted food ($Gr_1 = 1$). When taking into account decreases and increases in food loss in relation to the launch period, the rankings of countries with the greatest improvement in reducing food losses is represented a bit differently. In comparison, when we consider the extreme three-year periods, these countries with the highest decrease in nominal food waste had a lower position (see R_3 and R_4). In this approach, with the three- and six-year periods the leader of the ranking is Luxembourg (for Poland $R_3 = 6$ and $R_4 = 8$). Major changes in ranking of the countries according to their progress in reducing food losses occur in the case of index ξ_5 [formula (5)], which is the arithmetic mean of the S_i coefficients designated by methods GCA [formula (4)]. Poland is ranked in the seventh position ($R_5 = 7$), the leader is Cyprus again ($R_5 = 1$), but when it the positions of some countries such as France ($R_5 = 8$ when $R_1 = R_3 = 24$ or $R_2 = R_4 = 22$), Luxembourg $R_5 = 17$, when

Table 2. Indicators and rankings of changes in the level of food waste in 2000–2011 in the EU countries

	ξ_1	ξ_2	ξ_3	ξ_4	ξ_5	R_1	R_2	R_3	R_4	R_5	Gr_1	Gr_5
Austria	–0,013	–0,017	–0,054	–0,065	0,665	14	16	16	18	25	3	4
Belgium	0,157	0,099	1,096	0,493	0,595	28	28	28	26	21	4	3
Bulgaria	–0,029	–0,092	–0,103	–0,255	0,500	11	4	13	9	14	2	2
Croatia	–0,080	–0,076	–0,392	–0,352	0,417	5	6	2	2	6	2	2
Cyprus	–0,172	–0,176	–0,331	–0,322	0,230	1	1	4	4	1	1	1
Czech Republic	–0,028	–0,043	–0,234	–0,303	0,570	12	11	7	6	18	2	3
Denmark	–0,002	–0,025	–0,007	–0,079	0,583	18	14	19	17	20	3	3
Estonia	0,080	0,058	0,968	0,539	0,677	27	27	27	28	26	4	4
Finland	0,007	0,005	0,431	0,271	0,643	22	23	25	25	23	3	3
France	0,023	0,003	0,134	0,015	0,439	24	22	24	22	8	3	2
Germany	–0,022	–0,025	–0,129	–0,136	0,573	13	13	12	13	19	2	3
Greece	–0,115	–0,110	–0,224	–0,206	0,402	2	2	8	11	5	1	2
Hungary	–0,034	–0,022	–0,195	–0,130	0,465	10	15	10	14	11	2	2
Ireland	0,002	–0,009	0,009	–0,047	0,515	21	19	21	19	15	3	3
Italy	0,020	0,009	0,122	0,049	0,450	23	24	23	23	10	3	2
Latvia	–0,005	–0,009	–0,068	–0,108	0,645	17	18	15	16	24	3	3
Lithuania	–0,041	–0,074	–0,218	–0,327	0,335	9	7	9	3	3	2	1
Luxembourg	–0,048	–0,058	–0,403	–0,419	0,529	8	10	1	1	17	2	3
Malta	–0,013	–0,006	–0,068	–0,030	0,324	15	20	14	21	2	3	1
Netherlands	0,058	0,041	0,763	0,499	0,780	26	26	26	27	28	4	4
Poland	–0,097	–0,094	–0,269	–0,262	0,423	3	3	6	8	7	1	2
Portugal	–0,078	–0,084	–0,286	–0,309	0,496	6	5	5	5	13	2	2
Romania	–0,001	–0,026	–0,010	–0,158	0,754	19	12	18	12	27	3	4
Slovakia	–0,081	–0,066	–0,385	–0,298	0,439	4	9	3	7	9	2	2
Slovenia	0,030	0,027	0,101	0,088	0,622	25	25	22	24	22	3	3
Spain	–0,050	–0,072	–0,175	–0,228	0,337	7	8	11	10	4	2	1
Sweden	–0,005	–0,014	–0,048	–0,120	0,486	16	17	17	15	12	3	2
United Kingdom	0,000	–0,002	–0,002	–0,034	0,524	20	21	20	20	16	3	3
Mean	–0,019	–0,031	0,001	–0,080	0,515							
Standard deviation	0,062	0,055	0,375	0,254	0,130							

Source: Own calculation based on FAO data.

$R_1 = 8$, $R_2 = 10$, $R_3 = R_4 = 1$) and Austria ($R_5 = 25$ when $R_1 = 14$, $R_2 = R_3 = 16$, $R_4 = 18$) are considered, the changes are much more major. This causes obviously significant differences in regard to the composition of established groups (Gr_1 and Gr_5).

The compliance of indicators of changes in the loss of food values and set up the rankings depending on the approach to the problem is best shown in Table 3, which present the correlation coefficients between the designated indicators and the positions occupied by the individual countries.

The greatest similarities can be seen in the case of indicators and rankings for three- and six-year-periods determined nominal losses or in terms of relative to the launch period (coefficients of correlation between the indicators ξ_1, ..., ξ_4 and rankings R_1, ..., R_4 are valued above 0.8). However, there is a dissimilarity between indicators ξ_1, ..., ξ_4 and indicator ξ_5 and also rankings between R_1, ..., R_4 and R_5 ranking, where the correlation coefficients were at a noticeably lower level. But this should not raise any objections, since the method of determining the ratio ξ_5 significantly differs from the classic created indices ξ_1, ..., ξ_4. Index ξ_5 is built based on a measure of diversity ar, which is sensitive to the so-called transfers (a term commonly used in the concentration of income

Table 3. Matrices of correlation coefficients between the indicators and rankings of countries with the largest decrease in food waste

	ξ_1	ξ_2	ξ_3	ξ_4	ξ_5
ξ_1	1				
ξ_2	0,961	1			
ξ_3	0,857	0,812	1		
ξ_4	0,828	0,840	0,969	1	
ξ_5	0,635	0,646	0,560	0,567	1

	R_1	R_2	R_3	R_4	R_5
R_1	1				
R_2	0,940	1			
R_3	0,948	0,876	1		
R_4	0,887	0,912	0,941	1	
R_5	0,652	0,564	0,563	0,511	1

Source: Own calculation based on FAO data.

field), which clearly differentiates movement of the same waste volume of between the years. A measure of diversity ar [formula (1)] has the greater value with the offset value of the waste on time takes place on a larger time interval [Binderman et al. 2014, Koszela 2016]. Therefore, the approach to the problem is much different from those considered as classical ones. What is more, the GCA instrumentation giving additional graphical interpretation in the form of over-representation maps (Fig. 1) may be an important warning before releasing the ranking built only on the basis of a synthetic index constructed with the use of well-known classical technique.

CONCLUSIONS

Food production is associated with a significant burden on the environment so the constant monitoring of changes in the level of waste food products in the EU is very important. It is crucial that changes of the level of food waste were characterized by a descending trend. One of the activities in support of the administration actions in the individual countries in this area are publications of all kinds of rankings depicting the situation in terms of food wastage. However, the construction of the rankings, especially when they are published should take care that they have a high stability (more about this issue has been widely discussed [Koszela and Szczesny 2015]. In this paper, to the construction of synthetic indicators describing the change in level of waste a simplified approach was used, and found all categories of food products as equally important (equal weights applied). As described in the introduction, examples of water demand indicate that the problem of the ranking construction is much more complicated, and the adoption of the same weight was dictated by the limited paper volume. Verification of the stability of the presented ranking should not be reduced to checking the impact of weights on the order results only (and the assessment of the level of changes using the synthetic indicators). To make sure that the published ranking is stable it should be compared with others created by different techniques. The paper compares two types of rankings of changes level obtained by two different techniques (using the change in the value of the synthetic indices assessing the level of waste and using ordering obtained by GCA tools differentiation of structures index ar). From the results presented in Tables 2 and 3 it is clear that the arrangement of objects on the index ξ_5 are more different from orders of the index values of ξ_1, ..., ξ_4 than the arrangements between them (see correlation matrices in Table 3). In particular, the positions of countries like Austria or France considerably vary (sometimes by more than 10 ranks). It is worth noting, that using techniques with GCA instruments to rank countries according these seven variables, we have a clear graphics interpretation in the form of seven overrepresentation maps.

The comparison was made on the assumption that the reduction of waste is equally valid in each of seven or eight-aggregated product groups. These rankings give an initial picture of the ongoing changes, because they do not reflect e.g. how these changes affect the change of load on the environment (greenhouse gas emissions, water consumption etc.). For this reason, it seems that more detailed periodical reports on an annual basis should be published, taking into account changes in the value of waste in the narrower product groups using weights proportional to the load on the environment in their production.

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ZMIANY POZIOMU MARNOTRAWSTWA ŻYWNOŚCI W KRAJACH UE

STRESZCZENIE

Marnowanie żywności to problem społeczny i ekonomiczny, jest także dużym i niepotrzebnym obciążeniem dla środowiska naturalnego. W pracy podjęto problem porównania zmian dotyczących poziomu marnotrawstwa żywności w krajach UE w latach 2000–2011. Posłużono się tutaj dwoma technikami: wielowymiarową analizą porównawczą oraz gradacyjną eksploracją danych. Druga z nich jest zastosowana pierwszy raz w tego typu zagadnieniach. Na podstawie tych technik zbudowano wskaźniki syntetyczne, które posłużyły jako kryterium klasyfikacji krajów UE pod względem tempa zmniejszania poziomu marnotrawstwa żywności. Okazuje się, że zastosowane do budowy wskaźników techniki dają w efekcie różniące się od siebie uporządkowania.

Słowa kluczowe: wielowymiarowa analiza porównawcza, gradacyjna eksploracja danych, wskaźnik syntetyczny, klasyfikacja obiektów, marnowanie żywności