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Use of Automatic Dishwashers and Their Programs in Europe with a Special Focus on Energy Consumption

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Abstract: Due to the current high awareness and rising energy costs, the energy label of domestic appliances is an important indicator for consumers when buying a dishwasher. However, not all consumers use efficient Eco cycles on a regular basis. When investigating the use of domestic dishwashers and the chosen programs in a survey with 6090 participants from 11 countries in Europe, it turned out that only 25% used Eco cycles regularly while the vast majority of 48% prefer to use Normal/Auto cycles. We also assessed individual energy and water consumption as well as duration and temperature of the programs. Considering the fact that Eco programs are not well accepted due to their duration, our study shows that Short programs, which on average only last about 30 min and consume little energy and water, might be an economical and convenient alternative to the more time-consuming Eco programs. In fact, some Short programs considered in this study proved to consume less energy for a full dishwasher load (0.74 kWh on average) than the standard Eco programs (0.90 kWh on average), especially due to their shorter duration, but it is important to note that, according to the manufacturer, these programs are designed for rather lightly soiled dishes.

Keywords: dishwasher; short cycle; quick cycle; eco cycle; auto cycle; energy consumption

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1. Introduction

Population growth and improvements in living standards, especially in industrialized nations, have led to an increase in the use of household electrical appliances [1]. In Germany, the equipment of private households with automated dishwashers reached 74.6% in 2022 [2]. In recent years, appliance manufacturers have developed dishwashers that conveniently save energy, water and time; more than 30% of energy consumption has been saved over the past 20 years, and the average water consumption per wash cycle has been cut by more than half [3]. Energy-saving domestic appliances are of great interest to the consumer especially since displaying the efficiency classes is mandatory due to the EU-wide regulations and requirements for dishwasher manufacturers [4]. Moreover, a rising awareness for energy saving even among consumers can be expected due to the increasing presence of the topic in the media. In this regard, Geetha and Tyagi confirmed in their 2016 study that dishwashers with a low consumption of water and energy are desired by many consumers [5]. However, an online survey of 2006/2007 with 1206 participants from Germany, Italy, Sweden, and the United Kingdom (UK) showed that Normal/Regular dishwasher programs or Intensive cycles were used most frequently (40%) while the generally less consumptive Eco cycles were only used by 17% [6]. One reason for this was supposed to be a relatively low acceptance of dishwasher cycles lasting longer than two hours, although 35% of the surveyed persons stated that they would generally accept longer cycles to save energy [7]. Overall, the majority of consumers are not willing to use long-lasting cleaning cycles [7–11]. The Eco cycle was defined as a test program for declaration purposes and therefore has the lowest possible energy and water consumption

when cleaning normally soiled dishes [7]. In addition to the numerous cleaning programs of modern dishwashers, which are related to the items to be cleaned, there are also additional functions that, for example, lead to a shorter duration, additional pre-rinsing or increased temperatures. These functions, like the programs themselves, often have different names with different manufacturers. It is of particular importance in this regard that the Normal cycle, which is used by a large majority of consumers [6] and is also referred to as "Daily", "Regular" and "Standard", shall no longer be used as the default option for household dishwashers due to new legislations (mandatory since March 2021) [12]. Regarding program duration, a consumer study from 2007 covering about 2500 households from ten European countries found that a short duration is important to 18.5% of the users [13]. A Greek study also showed that convenience was one of the major reasons why consumers own automatic dishwashers [14], which could also support consumers' preference for Short programs. Short programs with less than 55 min and an average cycle length of about 30 min and temperatures at about 45 °C are not only convenient, but can also have low energy consumption, which could make them particularly interesting for everyday use. Nevertheless, it must be noted that next to energy and water consumption, clean dishes are one of the main interests of consumers [5]. Short cycles are recommended by manufacturers for rather lightly soiled dishes [3] and can often only achieve clean dishes through elaborate pretreatment. According to Sinner [15], the interaction of temperature, the chemicals used, the mechanics and the washing time is necessary for the cleaning process [16]. The cleaning result is only satisfactory if the individual parameters are appropriately pronounced [16]. However, the so-called Sinner's circle also states that it is possible to replace the activity of one of the parameters with another without negatively affecting the cleaning result [16]. This possibility is frequently used today in the creation of optimized programs, e.g., for ecological programs by reducing the temperature while increasing the program duration [16] or for Short programs by reducing the time but increasing the temperature or increasing the use of chemistry.

In this study, we compiled data on energy consumption, water consumption, duration, and temperature of the cleaning cycles of domestic dishwashers in Europe as well as the preferred programs in 11 different countries and the resulting individual consumption of energy, water and time. Considering these data might thus help to enable efficient dishwashing procedures with an optimized profile in terms of energy and water consumption. It has to be mentioned that, effective March 2021, a new Eco-design regulation was implemented in the European Union that might impact the use and energy consumption of domestic dishwashers, since manufacturers will strive for even more efficient programs using lower temperatures. One of the main changes that was introduced by the novel regulation is related to program names, since new dishwashers must comprise an "Eco" program that is not allowed to be named otherwise. Since the appliances in this study were marketed according to the old Eco-design regulation, program names may vary.

This work presents the current situation in more detail in order to create the basis for our further research. The fact that certain Short cycles can consume as much or even less energy and water than Eco programs highlights the importance of research into the cleaning performance of Short cycles in combination with certain cleaners. Should this be possible, consumers could save not only energy and water but also time.

2. Materials and Methods

To support technical data and giving deeper insights to the age of the machines and user's habits, a survey of 509 people in the United Kingdom (UK), 520 people in France (FR) and 503 people in Belgium (BE) owning a dishwasher was performed. The survey was conducted online with the platform Toluna (www.toluna.com (accessed on 25 February 2022)) between December 2021 to February 2022. The questions targeted the age of the machines and the frequency of their use. The panel was also asked about the type of possible pre-treatments of the dishes before dishwashing and the duration the dishes

stayed in the dishwasher before starting. The following questions are part of our study and the answer options of question 1 and 2 are shown in the results section:

1. How old is your dishwasher (please select 1 answer).
2. The last time you ran your dishwasher more than 1 cycle per day or more than 7× per week, what was the main reason for running the second cycle?
3. Before putting the dishes into the dishwasher, do you typically do any of the following pre-treatment procedures? Select all that apply.

- o Do nothing, place the item directly into the dishwasher in their current condition.
- o Only scrape food off the item (no rinsing or use of dishwashing soap).
- o Rinse the item with water only and place in the dishwasher.
- o Scrub item with water only with a sponge/scrubber/cloth and place in the dishwasher.
- o Soak item with water only then rinse/scrub with water before placing into the dishwasher.
- o Scrub item with dishwashing soap and water with a sponge/scrubber/cloth and place in the dishwasher.
- o Soak item with dishwashing soap and water then rinse/scrub with water before placing into the dishwasher.

To gain information about the available and actually used cycle types, a representative survey with 6090 participants from United Kingdom (UK) (n = 506), France (FR) (n = 520), Belgium (BE) (n = 503), Spain (ES) (n = 607), Italy (IT) (n = 652), Greece (GR) (n = 591), Poland (PL) (n = 527), Sweden (SE) (n = 509), Turkey (TR) (n = 536), Russia (RU) (n = 578) and Israel (IL) (n = 561) was performed at the same time and platform mentioned above. The participants were asked what the model of their dishwashing machine was, and they were asked to name all the cycles that were available on their dishwasher. They were also asked to name the cycle most often used (Top 1). Table 1 depicts the examined countries, number of evaluable respondents and the number of households in the different countries.

Table 1. Examined countries, number of evaluable respondents and the number of households in the different countries.

Country	Respondents	Households [1]	State of Information [1]
UK	506	27,824,000	2019
FR	520	27,106,517	2010
BE	503	4,762,737	2013
ES	607	18,625,700	2019
IT	652	25,508,000	2019
GR	591	4,134,540	2011
PL	527	13,567,999	2011
SE	509	4,718,271	2019
TR	536	24,001,940	2019
RU	578	54,560,627	2010
IL	561	2,667,600	2019

[1] Source: UNECE Statistical Database, compiled from national official sources.

In addition, comprehensive data were collected from the manuals of 164 full-sized dishwasher models from 31 best-selling manufacturer's representatives of the installed base of the European market (euromonitor.com (accessed on 28 October 2021), including the type of programs present and their energy and water consumption, as well as the duration of the programs and temperatures (Supplementary Material S1). From these data, mean values for energy and water consumption as well as the cycle duration and temperature of all programs were calculated and compared.

3. Results and Discussion

3.1. Age of Dishwashers

As shown in Figure 1, most respondents (46.1%) from the survey indicated that their device was between 0 to 3 years old, while 32.1% of the people reported owning a device

between 4 to 6 years old and 13.5% had devices between 7 to 10 years old. Machines older than 10 years were used by 6.4%. The majority is therefore using a relatively new dishwasher, which is important for the interpretation of the technical parameters presented later. These findings are very much in line with the results by Hook et al. who, in a similar survey, concluded that the age of the dishwasher was on average 5.2 years and more than 50% of the dishwashers were 4 years old or less [7]. Another German study from 2009 reports that the devices within their study were on average 6 years old [17].

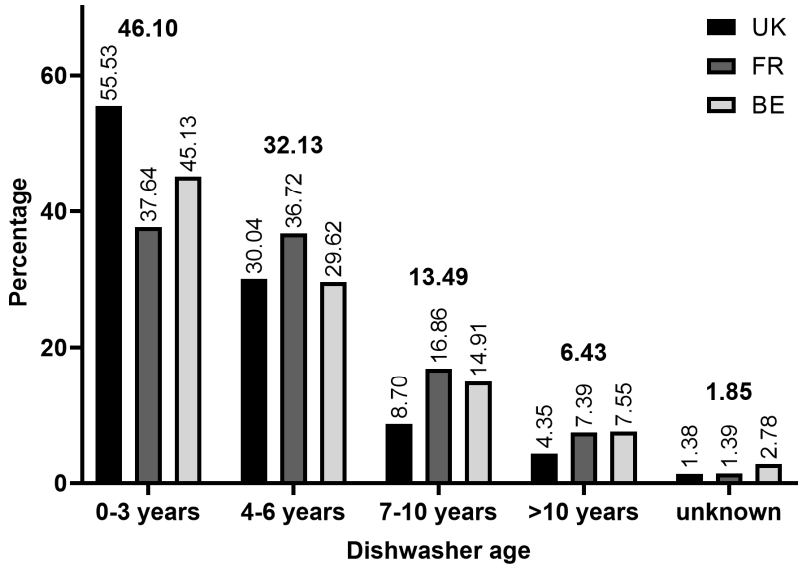

Figure 1. Age distribution of dishwashers in all surveyed countries with the respective mean value of a response across UK, FR and BE.

3.2. Frequency of Dishwashers' Use

Figure 2 illustrates that the majority of surveyed households do not use their dishwasher more than seven times a week (79.3%). About 20% claimed that they use more than seven cycles per week. The main reasons given in the questionnaire was that participants stated to have too many dirty dishes to wash (9.5%) so that not all the dishes would fit in one load or that they would usually run a load during the day and another one at night (4.7%). Only 3.3% declared that they have not enough dishes to cover their day, which often means that very specific dishes needed are dirty, while 2.6% reported that they prefer washing in the dishwasher over hand cleaning, resulting in more than one cycle per day. In regard to the frequency of dishwasher use, also of interest is a finding from Richter's 2010 study where dishwashers were loaded to maximum capacity in less than 40% of all wash cycles [6].

3.3. Pretreatment of Dishes

Concerning the pretreatment of dishes, 36.5% of the respondents stated that they rinsed the items with water before putting them in the dishwasher while 47.7% only scraped off possible food residues (multiple answers were selectable). Very few people indicated the use of additional mechanics, such as soaking or the use of dishwashing soap to pre-clean the items (Figure 3). Only 13% of the UK participants put their dishes directly into the dishwasher without any pretreatment, whereas in FR and BE about 30% responded that they did so. Although using a dishwasher seems not only to be more hygienic, but also significantly more resource-efficient than washing dishes by hand [18], pre-rinsing diminishes or even eliminates this advantage. Therefore, reducing the habit of pre-rinsing must be considered an important leverage to enhance resource-efficiency in dishwashing. Consumers should avoid pre-rinsing by hand, as this is supposed to consume even more water and energy, especially when using warm water [6], although a direct comparison of

the energy used for prerinsing or an adjusted Auto program cannot be drawn easily. In their 2015 study, Bichler et al. showed that households that predominantly use the Eco program also prewash dishes more frequently and thus consume additional resources [19].

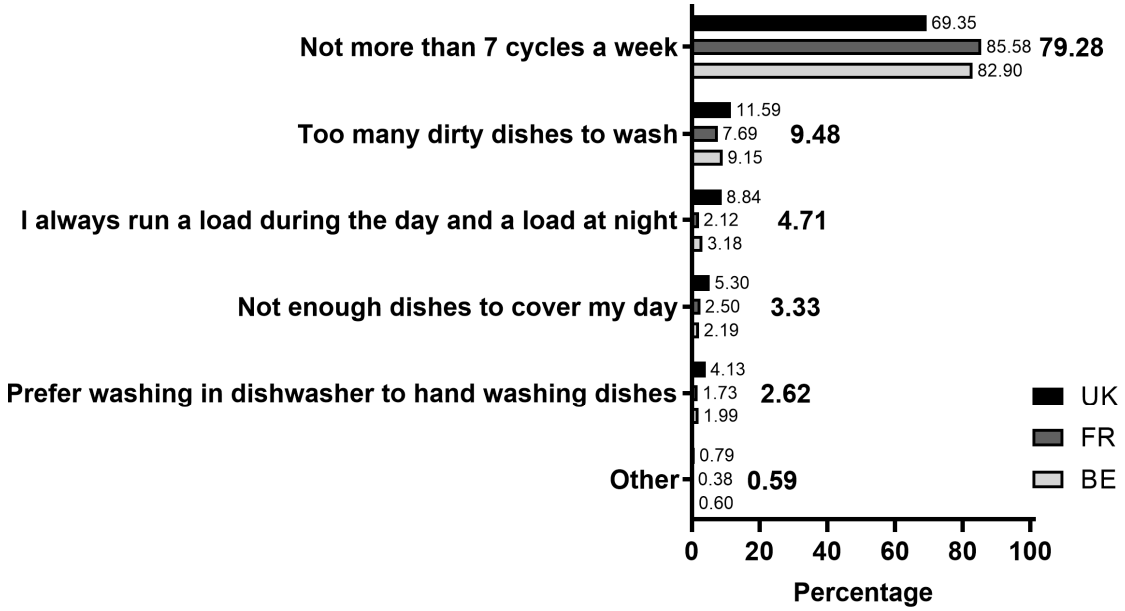

Figure 2. Reasons for more than 7 cycles a week with the respective mean value of a response across UK, FR and BE.

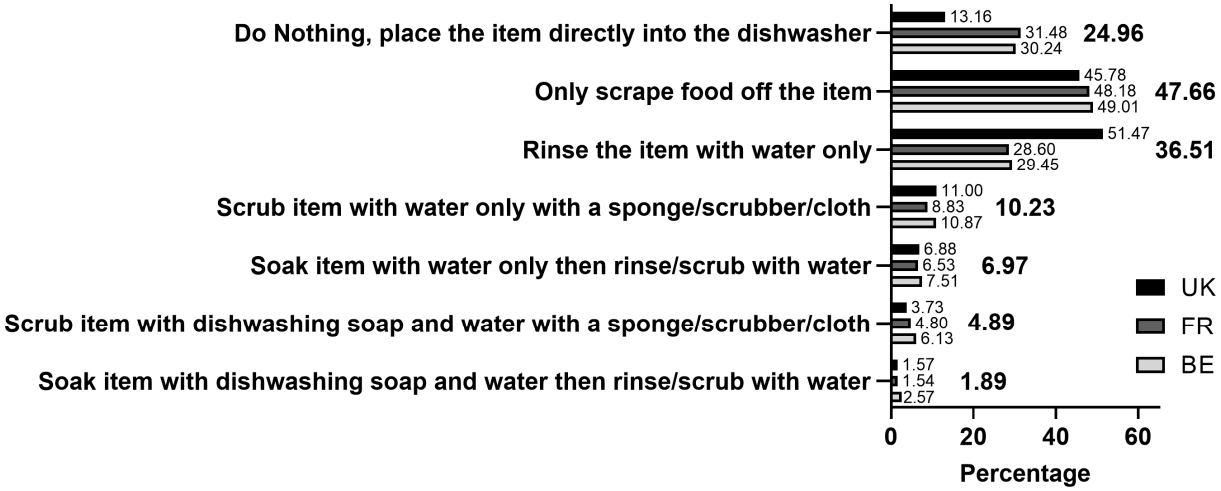

Figure 3. Pretreatment of dishes with the respective mean value of a response across UK, FR and BE.

3.4. Available Cycles and Their Consumption of Energy, Water and Time

Of the 164 types of dishwashers investigated in UK, FR, BE, ES, IT, GR, PL, SE, TR, RU and IL, Table 2 shows the names of the programs present in the devices with a brief explanation and typical terms from the manufacturers. Not apparent to the average consumer, but still important, is that the Auto cycle is separable in different subcategories like Auto 45 °C, Auto 55 °C and Auto 65–70 °C (and the dishwasher machine chooses the appropriate condition based on the sensor it uses). When the parameters of Auto cycle are referred to in this study, it is the average of the Auto cycles with higher main wash temperatures (Auto 55 °C, Auto 65–70 °C) as this refers to the temperature used when using a fully loaded or soiled load machine. The individual parameters are shown in Supplementary Material S2.

Table 2. Used designations for cycles and explanation/ typical manufacturer terms.

Designation	Explanation/Manufacturer Terms
Short	Short/Quick cycles, rapid, fast, express, mini function
1 h	One-hour cycles, express, strong and fast, daily, autofast, quick powerwash
Normal	Normal cycles
Auto	Auto cycles 45 °C, 55 °C, 65–70 °C, sense, sensor wash
Eco	Default Eco cycle
Intensive	Intensive cycles 60–75 °C
Glass	Glass cycle 40 to 50 °C

Using these program groups, energy and water consumption were calculated and mean values are shown in Figure 4. Energy, water and time take into account the full cycle while temperature refers to the main wash temperature. The energy consumption applies to fully loaded machines, which is important because the number of place settings has an influence on the energy consumption. It can be seen that Short cycles use the least energy (0.74 kWh), use approximately 10.4 L water, take 31 min on average (max = 50 min; min = 20 min), and clean at approximately 45.3 °C. Generally, the Eco cycles (averaging approximately 48.9 °C) have higher consumptions than Short cycles at 0.90 kWh. Water consumption in Eco is around 11 L and the duration is 197 min. The energy consumption of the Normal cycles is rather in the upper range (1.32 kWh). Their water consumption (15.2 L) is also above average and the average temperature of the Normal cycles is 59.4 °C. The cycles with the highest energy and water consumption are Intensive cycles with an average of 1.55 kWh and about 16.7 L of water. These cycles take an average of 149 min and reach 67.4 °C, the highest average temperature of all the cycles examined.

As far as Auto cycles are concerned, soil, detected via turbidity measurement, must be considered as a trigger for higher temperature, duration, and water consumption. Auto programs with only 45 °C use for example only 0.84 kWh on average, the least water (8.6 L), and are second fastest, but are significantly longer (101 min) (Supplementary Material S2) than Short cycles (31 min). It should be mentioned that the temperature and duration of these Auto programs may largely vary with the amount of soil present. The results of tests confirming this are in Supplementary Material S3. Since 46% of the respondents from the UK only scrape off food residues and 13 percent put the dishes directly into the dishwasher (resulting in higher amounts of soil and residues), it must be assumed that Auto cycles with higher duration and temperature and thus higher energy consumption are not uncommon, while minimum values for the parameters, as indicated in the dishwasher manuals, may virtually never be reached (as these consumption numbers are only achieved when running an empty machine). For this reason, the mean value of the Auto cycles in this study (Figure 4, Table 3) was formed without the Auto 45 °C, since this cycle is very unlikely to ever be used in practice. From the significance indicators of Figure 4, it is clear that the Auto cycle and Normal cycle never differ significantly, neither in energy and water consumption nor in temperature and cycle length. In fact, Normal and Auto cycle are consistent in all compared parameters. Table 3 contains the data basis for Figure 4 and the detailed standard deviations.

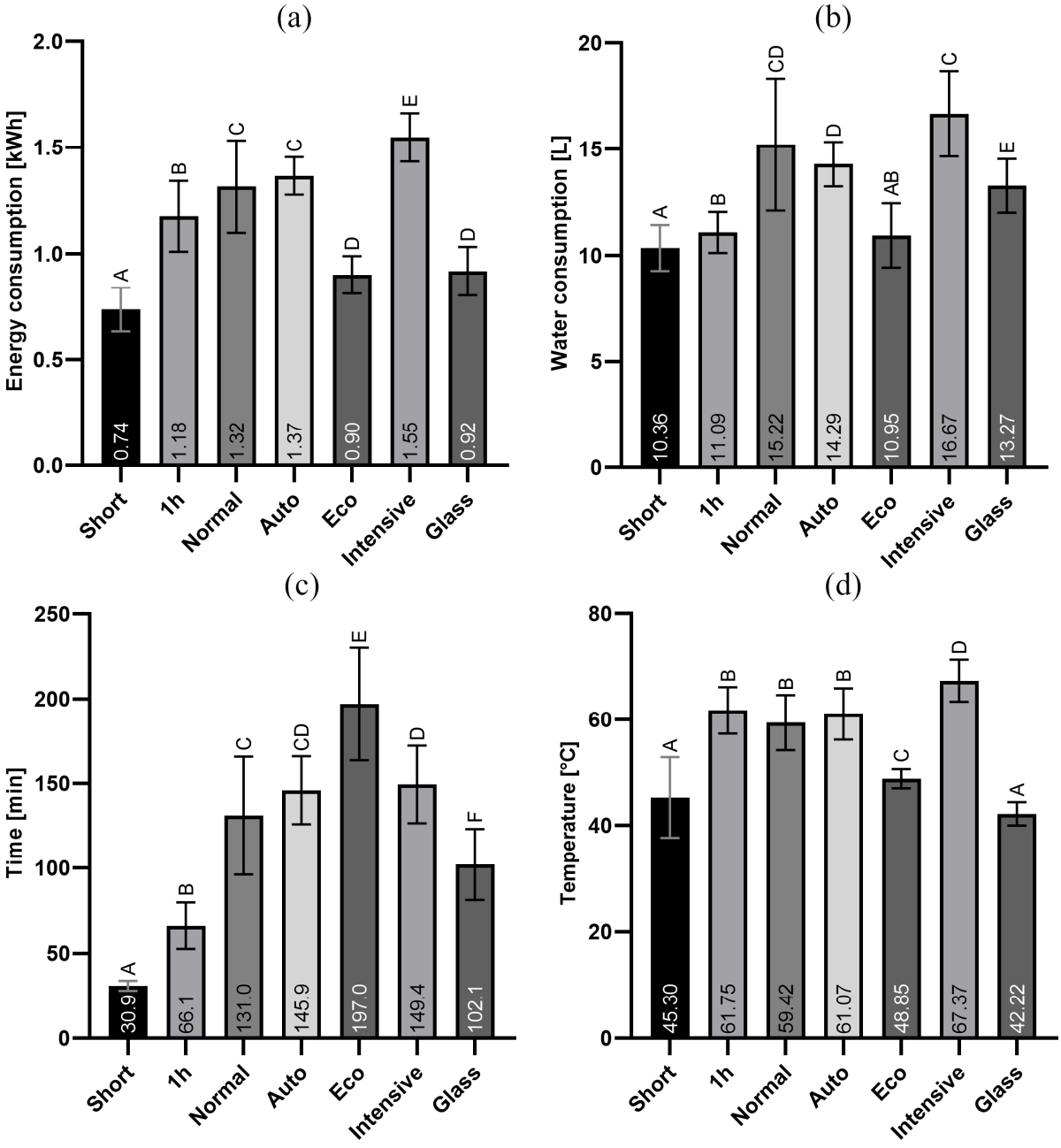

Figure 4. Average energy consumption (**a**), water consumption (**b**), duration (**c**) and temperature (**d**) of corresponding cycles. Different letters (A–F) indicate significance differences using unpaired *t*-tests with Welch's correction (statistical significance $p < 0.05$). Same letters mean no significant differences and different letters mean the differences are significant.

Table 3. Average energy consumption, water consumption, duration and temperature of corresponding cycles with standard deviation.

Cycle	E (kWh)	SD	W (L)	SD	t (min)	SD	T (°C)	SD
Short	0.737	0.103	10.36	1.08	30.90	2.89	45.30	7.61
1 h	1.176	0.166	11.09	0.96	66.13	13.55	61.75	4.40
Normal	1.316	0.217	15.22	3.10	130.97	34.84	59.42	5.21
Auto	1.366	0.089	14.29	1.05	145.92	20.07	61.07	4.87
Eco	0.901	0.088	10.95	1.51	197.03	33.31	48.85	1.81
Intensive	1.548	0.114	16.67	2.01	149.38	22.92	67.37	3.97
Glass	0.918	0.114	13.27	1.26	102.13	20.99	42.22	2.19

3.5. Cycle Use in European Countries

The EU regulation published in 2019 and enforced in 2021 states that the indications "normal", "daily", "regular" and "standard" and their translations in all EU official languages shall not be used in program names for the household dishwasher, neither alone nor in combination with other information. The normal program might therefore be replaced by the auto program. It must be considered that a dishwasher rarely contains both Auto and Normal cycles, but either one or the other. Therefore, Auto and Normal are recognized as the same program. However, it must be pointed out that Normal and Auto programs are not the same thing, as Auto programs require turbidity sensors and are therefore typically found in more expensive dishwashers. As shown in Table 4, seven programs were favored by the respondents. In all the countries studied, the Normal or Auto cycle was the most used (48%). The second most used cycle was the Eco cycle, on average used most frequently by 25% of respondents. This is in line with the findings of Hook et al., who found 19% using Eco in a 2018 European survey with 5277 participants [7], although a slight increase in the use of the Eco program in recent years could be assumed. In Italy only, the use of Eco cycle (36%) is almost as high as Auto cycle (37%). The third most used cycle was the 1 h cycle (e.g., express, strong and fast, daily, autofast, quick powerwash), being the most frequently used program for 12% of the respondents on average. The use of the 1 h cycle is particularly high in France (19%). Finally, the Quick or Short cycle is used on average only slightly more often (7%) than the Intensive cycle (6.6%). In Italy, the Quick/Short cycle is more popular (12%) than in all other countries included in the study. Here, like in Sweden, the number of consumers pretreating their dishes under continuous running water is very high [20], which may be a reason for the somewhat more frequent use of Short programs in Italy. On average, a neglectable amount of 1.1% stated that they used the Glass/Delicate cycle as the Top 1 cycle and 0.9% were not assignable. Stamminger and Streichardt estimated in 2009 which dishwasher programs were chosen in Germany, based on a survey which gave the choices always, often, sometimes, seldom and never for the use of programs [17]. Accordingly, the Normal programs 60–65 °C (29.1%) and Normal 50–55 °C (27.7%) were used most frequently [17], which generally consume more energy and water than the Eco or saving program, which was selected 17.7% of the time in this publication. The Quick program was only selected by 8.7% [17]. Another study looking at consumer program choices for dishwashers was recently published [21].

Table 4. Percentage of the most used (Top 1) dishwasher cycles in 11 different countries.

Cycle	UK	FR	BE	ES	IT	GR	PL	SE	TR	RU	IL	Avg.
Short	6	5	5	6	12	10	9	8	3	6	7	**7**
1 h	11	19	14	14	5	7	14	8	12	9	15	**12**
Normal/Auto	53	42	46	46	37	46	49	53	39	67	47	**48**
Eco	24	24	27	29	36	28	21	26	34	14	16	**25**
Intensive	5	9	8	4	8	7	5	4	10	4	9	**7**
Glass	1	0	0	1	1	1	1	1	2	1	3	**1**
Not assignable	1	1	0	1	1	2	1	0	1	0	2	**1**

3.6. Consumption of Energy, Water and Time in Investigated Countries

Figure 5 shows a map compiling the consumption of energy, water, time and the average cleaning temperature in each country, taking into account the percentages of the most popular programs (Table 4) in each case and the consumptions of the individual dishwasher models (Supplementary Material S2) as well as the percentage of used dishwashing models in the different countries where known (Supplementary Material S4).The values therefore indicate the consumption of an average cycle based on the percentage and the individual consumption of the models used in a country. The small percentages of 0 to 2% of not assignable cycles (Table 4) were not included in the calculation. Where individual values of parameters of specific programs/brands were not known, appropriate mean values were

used. The exact procedure for the calculation can be taken from the following formula and the legend also describes where which values can be found.

$$X = \sum_{i=1}^{P} W_i \left(\sum_{j=1}^{H} W_j * X_{i,j} + \overline{W}_j * \overline{X}_i \right)$$

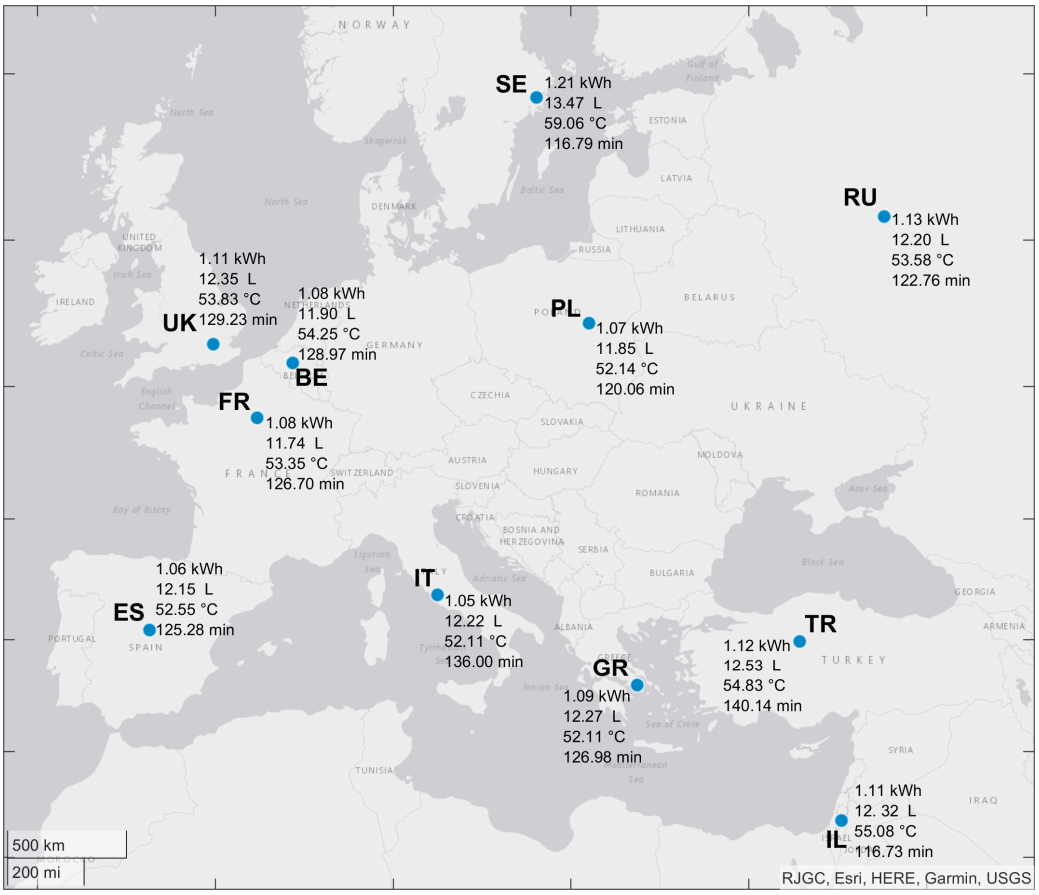

Figure 5. Map with average energy consumption, water consumption, temperature and time of one average cycle taking into account the percentage of cycles used (Table 4), the consumptions of the individual dishwasher models (Supplementary Material S2) and the percentage of used models where known (Supplementary Material S4).

X = parameter (energy consumption, water consumption, temperature, time).
i = program.
P = number of programs = 6 (Table 4).
W_i = weighting factor or percentage of program (Table 4).
j = dishwasher model/brand (Supplementary Material S4).
H = number of dishwasher brands = 25 (Supplementary Material S4).
W_j = weighting factor or percentage of model/brand (Supplementary Material S4).
$X_{i,j}$ = parameter for specific program and model/brand (Supplementary Material S2).
$\overline{W}_j$ = weighting factor or percentage of unknown model/brand (Supplementary Material S4).
$\overline{X}_i$ = average of a parameter of all models/brands (Supplementary Material S2).

It should be mentioned that the fact that a certain program was used most (Table 4) does not necessarily mean that this program is used in the majority of cases. Nevertheless, this program resembles an "average" cycle in the sense that no other cycles are used more often.

When the average energy consumption per cycle in the different countries is considered, the rather low variation becomes obvious (Table 5). On average, about 1.1 kWh are used, and the standard deviation is 4.14%.

Table 5. Average energy consumption, water consumption, temperature and time of one average cycle taking into account the percentage of cycles used (Table 4), the consumption of the individual dishwasher models (Supplementary Material S2) and the percentage of used models where known (Supplementary Material S4).

Country	E (kWh)	W (L)	t (min)	T (°C)
UK	1.11	12.35	129.23	53.83
FR	1.08	11.74	126.70	53.35
BE	1.08	11.90	128.97	54.25
ES	1.06	12.15	125.28	52.55
IT	1.05	12.22	136.00	52.11
GR	1.09	12.27	126.99	52.62
PL	1.07	11.85	120.06	52.15
SE	1.21	13.47	116.79	59.06
TR	1.12	12.53	140.14	54.83
RU	1.13	12.20	122.76	53.58
IL	1.12	12.32	116.73	55.08
Mean	**1.10**	**12.27**	**126.33**	**53.95**
SD [%]	**4.14**	**3.76**	**5.8**	**3.67**

Water consumption and duration also show a low standard deviation of 3.8% and 5.8%, respectively. For temperature, which averages 53.9 °C and shows a standard deviation of 3.7%, the maximum is in Sweden (59.1 °C) and the minimum is in Italy (52.1 °C). Sweden is the country with the highest energy and water consumption per averaged Top 1 cycle, Italy the country with the lowest energy consumption and France has the lowest water consumption. Although the averaged cycle energy consumption is the lowest in Italy (Figure 5), the pretreatment of dishes with water is relatively high there [20], which also consumes a lot of energy and water. Table 5 lists the data basis for Figure 5 and the standard deviations in%.

For Figure 5, it must be mentioned that energy and water consumption from pretreatment of the dishes are not considered. If one relates the results of the three surveyed countries from Figure 3 to the corresponding values from the map (Figure 5), the following hypotheses can be considered: In the UK, dishes are rinsed with water more often than in FR and BE, therefore lower energy and water consumption of the dishwasher could be expected in the UK, as more pre-cleaning has already taken place and therefore less consumptive programs are needed. However, the data do not confirm this hypothesis, as both water consumption and energy consumption (for the averaged Top 1 cycle) are higher in the UK than in FR and BE, despite more pre-treatment of the dishes. The causes for this could be the influence of the type of devices used or that the consumer's dishes pretreatment has no effect on the program selection. While there may be similarities in the approach to energy efficiency standards and labeling between EU and non-EU countries (Israel, Russia), it is important to note that there may be differences in the specific criteria, rating scales and test methods used. These variations could impact the comparability of energy efficiency ratings between regions. Therefore, it is essential to consider the specific standards and labels applicable in each country when evaluating the energy efficiency of dishwashers.

Figure 6 shows a Sankey chart with the Top 1 cycles averaged over all countries as a proportionate input and the resulting percentage of energy consumption. It is particularly striking that Short cycles are selected as the Top 1 cycle by 7% but account for only 4.38% of total energy consumption. This effect can also be observed with Eco. The 25% Top 1 Eco results in only 19.10% energy consumption. In the 1h program, the 12% selection almost corresponds to the proportional energy consumption (11.97%). The 48% Normal/Auto

proportionally accounts for 54.59% of the energy consumption. The share of energy consumption for Intensive is 9.19%, although only 7% select this as the Top 1 cycle. The diagram illustrates the savings potential when using Short or Eco cycles, whereby again the resulting cleaning performance must not be forgotten.

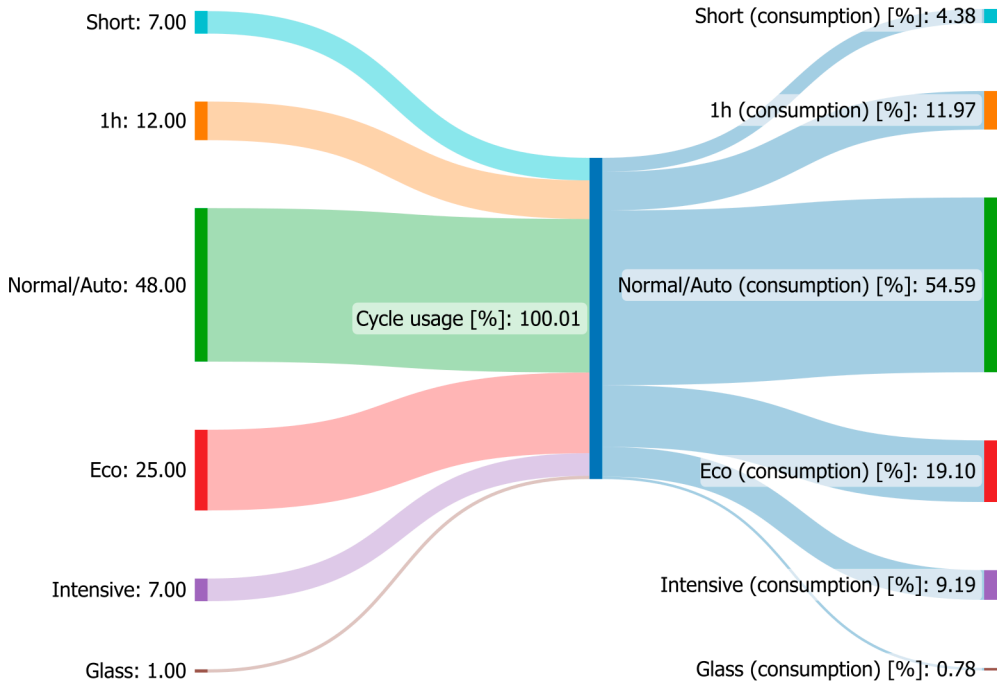

Figure 6. Sankey chart with the Top 1 cycles averaged across all countries as the proportionate input and the resulting percentage proportionate energy consumption as the output. Created via https://sankeymatic.com (accessed on 12 September 2023).

4. Conclusions

Almost the half of the consumers in the investigated countries (48%) use the Normal/Auto cycle as their preferred program, while the manufacturer default Eco programs are used less often as the preferred cycle (25%). This might reflect the ambiguity/variability in consumers' behavior: On the one hand, low water and energy consumption are most important to almost everyone [6], yet Eco cycles are only used by a fairly small percentage [7], most probably because they are very time-consuming. Considering this, low-consumption Short programs could be a viable alternative for the future, since on the one hand, as we could show, Short programs generally consume less energy and water than Eco programs, and consumers to a large extent intuitively assume that Short programs are energy-saving/energy-efficient [22]. Although this is not true for all programs that are shorter than the Eco program since due to the shorter time, cleaning is often performed with higher temperatures and/or more water, we could show to be true for "real" Short programs, i.e., those <55 min, that the average cycle was 30 min. Nonetheless, the Short cycles (<55 min) that consume low amounts of energy and water might become a particular economical and convenient alternative to the long Eco programs. However, if these programs achieve poor cleaning performance, they are disqualified as an alternative. It may be possible to achieve cleaning results comparable to the Eco-program by making good use of Sinner's circle, i.e., by compensating for the lack of time with an effective dishwashing detergent. Nevertheless, this would have to be researched in more detail. For this reason, our subsequent research will focus on the cleaning performance of different Short cycles depending on specific cleaners.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/cleantechnol5030054/s1, Supplementary Material S1: Anonymized brands and models with their individual consumption of energy, water, time and temperatures; Supplementary Material S2: Information about average energy and water consumption, temperature and time of all cycles of the machines of different manufacturers; Supplementary Material S3: Auto cycle settings depending on soil presence; Supplementary Material S4: Anonymized brand distribution in 11 different countries in%.

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