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The Efficacy of Food Waste Reduction Strategies in an African Frontier Market Food Services Industry

Abstract

There is an exponential increase in environmental littering, mostly from solid waste such as plate waste. Several public health officials are developing numerous policy interventions to dispose of sustainably and reduce and, where possible, avoid plate waste. The study sought to determine the contribution of various meal components to plate waste and assess the efficacy of various plate waste reduction intervention strategies in Zimbabwe, a typical Southern Africa frontier market. Using 400 transactions analysed using Analysis of Variance (ANOVA), an experimental study of the three invention strategies: portion size reduction, price-per-weight, and meal variety were conducted in various cafeteria systems. A preliminary study was conducted to determine the highest contributor of plate waste. The results also revealed significant differences in plate waste of various meal components, with starch being wasted more, followed by vegetables and meat. The results indicated that all the interventions had a statistically significant effect on reducing plate waste. Also, there is equal efficacy among the three studied plate waste reduction interventions in the food-services industry. Implications and recommendations were proffered.

Keywords: plate waste, portion size reduction, price-per-weight, meal variety

1. Introduction

Food waste has become a global phenomenon threatening sustainable development goals (Xu et al., 2020; Krishnan et al., 2023). This is particularly the case with institutional food service establishments such as hospitals, prisons, and university canteens, considered significant sources of food waste (Strotmann et al., 2017). The consequences of food waste include but are not limited to food insecurity, amplified water, carbon and ecological footprint (Kaur et al., 2020). Furthermore, considering that a significant proportion of the world's population suffers from starvation, food waste raises ethical concerns (Wu et al., 2019).

Plate waste pertains to the portion of food served that remains uneaten and is thrown away (Williams & Walton, 2011). It is categorised into edible and inedible waste (Juvan et al., 2021). Plate waste is a significant source of food waste in the entire food supply chain and, therefore, merits the design and implementation of some reduction intervention strategies (Wu et al., 2019; Mike von Massow & Bruce McAdams, 2015). For clarity, plate waste is a subset of the broader concept of food waste. In other words, food waste may emanate from plate waste, among other causes of food waste, beyond this study's scope.

Extant culinary literature has identified several factors that contribute to plate waste generation, such as inappropriate portion sizes (Zhao & Manning, 2019), limited menu choices (Mirosa et al., 2016), and poor food quality (Zhao & Manning, 2019). Previous research has also attested to the fact that plate waste is a

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function of demographics such as levels of income (Xu et al., 2020), education level (Wu et al., 2019), and gender (Kuo & Shih, 2016). Consequently, plate waste can be mitigated by serving a variety of dishes (von Massow & McAdams, 2015), reducing portion sizes (Kaur et al., 2020), and charging meals based on the weight of food ordered (Zhao & Manning, 2019). Although some mitigatory strategies for reducing plate waste generation were suggested in the extant literature, their empirical testing remains under-investigated across various sectors of food service establishments. More hypothetical effort is still needed to detect the drivers of place waste (Dolnicar, 2021).

This study examines some of the factors that mitigate against plate waste in the food service industry. The study's first aim is to quantify plate waste generated from the three main constituents of the essential meal: starch, protein, and fiber. The study's second aim is to assess the efficacy of reducing portion sizes, price-per-weight, and expanded menu choices as interventions to plate waste generation. Through the above objectives, this study will make significant contributions by empirically validating the plate waste generation interventions suggested in the extant literature and testing those interventions using samples from largely under-researched third-world countries. The following section discusses the literature review, methods, results, discussions, and implications.

2. Literature review

2.1. Plate waste management

Plate waste is part of solid waste that needs to be effectively managed (Zhao & Manning, 2019). However, the adage that 'prevention is better than cure' prevails in most issues in general and in solid waste management in particular, and it is a boon in environmental sustainability (Spinelli et al.,2024; Manumpli et al., 2023; Shereni et al., 2023). A reduction strategy is part of the 3 R framework of reduce, reuse, and recycle (Mukucha et al., 2023; Matzembacher et al., 2020).

2.2. Theoretical framework and hypotheses development

2.2.1. Nudging theory

The overarching theory of the study was the nudging theory, which Sustein and Thaler popularized in their groundbreaking 2008 book. A nudge is a deliberate intervention or information that may influence a person's decision (Thaler & Sustein, 2008). A nudge is, therefore, not a compulsion, command, or law. Nevertheless, a nudge shapes the choice architecture such that an individual is likelier to choose the sponsor's preferred option. Cai (2018) succinctly explained that cognitive biases enable us to design and present information to individuals to influence human behaviour. A nudge acts as a rudder to steer an individual to make a desirable decision willingly. The theory has been noted to be effective in influencing health and nutritional choices by 15.3% (Arno & Thomas, 2016) and influencing the fullness of a meal plate and meal sizes (Ferriday et al., 2016).

2.2.2. Plate waste composition

The composition of the menu items constituted plate waste, which varies (Visschers et al., 2020) depending on culture, personal choices, portion size, and food availability (Zorpas et al., 2015). Past research has attested that plate waste is high on vegetables, followed by starch and protein (Blackstone et al., 2018). A typical Zimbabwean food plate comprises sadza (thick porridge cooked using maize mealie-meal) as the main dish, accompanied by a relish. The relish is usually made from various vegetables, such as pumpkin leaves, kale, and spinach. Meat such as beef, chicken, or goat forms part of the protein element of the relish. The everyday plant-based relish items are beans and peanuts. The three essential constituents of a meal generate differential volumes of weight. Food plate waste composition refers to the types of uneaten food that are discarded from

plates after meals (Visschers et al., 2020). Common food elements frequently found in plate waste include grains, vegetables, and meat (Blackstone et al., 2018).

Fruits and vegetables are often the most commonly wasted food items on plates (Thamagasorn & Pharino, 2019). This usually takes place when they are served in large portions or are prepared in a less appealing way to the patrons (Birch et al., 2007). Grains such as rice, bread, and maize meal are also frequently wasted, especially when served in large portions. Meat products such as beef, chicken, and fish are also frequently wasted, usually for overcooked or poor quality and texture (de Boer et al., 2014). A study by Charlebois et al. (2015) in Canada indicated that starch is an excellent component of plate waste, while research by Papargyropoulou et al. (2016) in Malaysia pointed to vegetables. Overall, understanding the composition of food plate waste can assist cafeteria managers in developing strategies for reducing food waste and promoting more sustainable eating behaviours. Therefore, based on previous research, it is plausible to anticipate that;

H1: There is a differential size of plate waste from constituent elements of menu items.

2.2.3. Plate waste reduction strategies

Food waste disposal management has traditionally been tilted towards relying on landfills (Kaur et al., 2020), compositing, pulping (Abdel-Shafy & Mansour, 2018), and incineration (Mian et al., 2017). All these strategies have a considerable carbon footprint. This resulted in a conceptualisation of the quadruple R framework consisting of reducing, reusing, recycling, and recovering waste (Feng et al., 2020; Li, Jin & Mundree, 2017). In this framework, reducing waste generation is the first line of defence and should be prioritised (Wandosell et al., 2021). Although several interventions to reduce plate waste have been suggested in the extant literature, the most conceptually viable are serving flexible portion sizes, setting prices based on weight per meal, and having menu choices.

Several studies have explored the effectiveness of nudges in reducing plate waste in canteens. One study conducted by Hanks et al. (2012) found that reducing the size of plates can significantly reduce plate waste. Previous research in the canteen type of food service establishments revealed that reducing food portions leads to decreased plate waste (e.g., Visschers et al., 2020). In a previous study by Freedman & Brochado (2010), reducing the portion size of French fries from 88 g to 44 g reduced plate waste by 86%. The nudge theory suggests that minor interventions such as portion size reduction can substantially reduce plate waste. It is, therefore, plausible to suggest that;

H2: Portion size reduction significantly leads to reduced plate waste.

The other effective nudge is to use price-per-weight to reduce plate waste (Visschers et al., 2020). This is more like penalising the patrons for ordering more than they can consume (Priefer et al., 2016). When food is priced per item, it can lead to serving more food than what may be desired by the patrons and subsequently generating plate waste (Ellison et al., 2019). However, when food is priced per weight, patrons take only the quantity they need and consume their entire meal (Visschers et al., 2020). This may be accounted by the guilty conscience that patrons may feel for wasting food they have paid for by weight (Zuraikat, 2018).

Several studies have shown that applying the price-per-weight strategy in cafeteria systems can substantially reduce plate waste. For instance, a research by Hanks et al. (2012) investigated the effectiveness of a pay-per-weight intervention strategy in reducing plate waste in a school cafeteria. The results revealed a 30% reduction in plate waste. Several studies have added empirical weight to the fact that price-per-weight leads to less plate waste (Zuraikat, 2018; Stancu et al., 2016). By using the price-per-weight system to reduce plate waste, individuals are prompted to be more conscious of their food choices and ultimately reduce the

amount of food that ends up being wasted (Visschers et al., 2020). Grounding in the nudge theory, it is therefore plausible to anticipate that;

H3: Price-per-weight strategy significantly leads to reduced plate waste

The nudge theory also accounts for the reduction in plate waste due to the provision of food variety. The other way the nudge theory can be applied to plate waste is by providing an assortment of various meals. By offering a variety of smaller portions of different meals, people are more likely to try other things without feeling like they need to take more significant portions of each item. Several studies have pointed out that food choices reduce plate waste (e.g., Xu et al., 2020). This is because patrons may leave a lot of food uneaten if they are served with a meal that is not their choice (Visschers et al., 2020). Limited options are standard in cafeteria systems (Price et al. 2017). Drawing from the nudge theory, several ways through which meal variety can meaningfully lead to reduced plate waste can be proposed. Through presenting a variety of smaller portions, patrons are more likely to take only what they will eat, ultimately leading to less food waste (Hanks et al., 2012). It is, therefore, plausible to suggest that;

H4: Food variety significantly leads to reduced plate waste

Based on the extant empirical literature, different meal components generate various quantities of plate waste, with starch anticipated to create more, followed by vegetables, meat, or protein. The extant literature has many intervention strategies for mitigating plate waste, but the most common are portion size reduction, pay-per-weight, and increasing meal options strategies.

3. Methodology

3.1. Research settings

A preliminary study was conducted at a university canteen using the essential meal commonly served in most canteens to determine the highest contributor to plate waste. The data was recorded for plate waste of starch, protein, and vegetables. The data related to the first experiment was collected from a workplace canteen of a large manufacturing firm. Data was collected from the employees over 2 weeks, excluding the weekends. A usual portion was served during the first week, and the baseline plate waste data was recorded. During the second week, the portion size was reduced without the customers being informed, and data for plate waste was re-recorded. The data related to the second experiment was collected from another workplace canteen of a large manufacturing firm. Data was collected from the employees over 2 weeks, excluding the weekends. The usual portion was served in the first week, and the plate waste data was recorded. In the second week, the pay-per-weight system was introduced, and data on plate waste was recorded. The data related to the third experiment was collected from another large manufacturing firm's workplace canteen. As with the other two experiments, data was collected from the employees over 2 weeks, excluding the weekends. The usual portion was served in the first week, and the plate waste data was recorded. In the second week, a meal variety was introduced, and data on plate waste was recorded.

3.2. Sample size determination

The generalizability of results in a quantitative study hinges upon having an appropriate sample size (Verma & Verma, 2020; Adam, 2020; Festing, 2018). The right sample size can be determined through several methods, including relying on precedents from previous research. This study chose a sample size of 400 per intervention based on the sample sizes in previous studies in the food service industry (e.g. Mukucha & Jaravaza, 2021; Mukucha et al., 2019).

3.3. Research design and sample selection

A quasi-experimental study was conducted to test the efficacy of the hypothesised interventions. The first experimental design was conducted in a cafeteria to test whether reducing portion size leads to plate waste reduction. The intervention involved reducing portion sizes. This was done by serving smaller portions of food than usual. A control group was included in the study. This group received regular portion sizes and was unaware it was part of a study. The amount of food left on each participant's plate was measured and recorded. This was done by weighing the plates before and after the meal.

The second quasi-experimental design for testing whether the price-per-weight intervention strategy leads to plate waste reduction was conducted with a sample of individuals who eat at a cafeteria system where food is sold by weight. The participants were divided into two groups: control and experimental. Both groups dine at the same cafeteria, where the experimental group is charged by weight for their food, while the control group is charged the regular price. Each participant's food waste was measured and recorded for a set period.

A third quasi-experimental design was used to test whether increasing menu variety reduces plate waste. The experiment was conducted in a cafeteria system where participants were randomly assigned to one of two groups: a control group and an experimental group. The control group received the regular menu with limited variety, while the experimental group received an expanded menu with more variety. Each participant's food waste was measured and recorded for a set period.

3.4. Measurement

In Zimbabwe, food is served as a single meal, creating a single source of waste. We segregated the waste into three categories of edible plate leftovers—inedible plate waste comprised of bones. In line with a study by Wu et al. (2019), we considered solid waste only while excluding liquid waste, mainly comprising soups. In line with a previous study by Strotmann et al. (2017), the weight of waste was recorded on a predesigned sheet. To ensure internal validity, efforts were made to ensure no extraordinary circumstances would trigger unusual plate waste, such as poor food quality, unpleasant dining environment, employee incivility, and foodborne disease outbreaks.

Plate waste is generally measured by weighing food, visual estimation of the size of the residual food in a plate, or the recall method, and the results are reported as the percentage of served food weight (Wu et al., 2019). The weighted method is the most accurate of the three despite requiring significant effort and time resources to complete. It can also interfere with normal food service operations. The visual estimation method uses a perceptual scale to estimate the proportion of unconsumed food. However, the visual estimation method is associated with subjective assessments, which need to be mitigated by higher inter-observer reliability (Williams & Walton, 2011). The recall method asks respondents to rate the amount of food they discarded over the past 24 hours. This method is less expensive and does not disrupt regular operations, although retrospective self-reported data may not provide accurate information on plate waste (Matzembacher et al., 2020; Visschers et al., 2020). In this study, plate waste was measured using an electronic scale.

3.5. Data analysis procedures

The data on determining the differential waste from various meal components was assessed using the Analysis of Variance (ANOVA). ANOVA was favoured because it is suitable for comparing several categories of an independent variable, which in this study relates to portion size reduction, price-per-meal, and meal variety, over a metric-dependent variable, which in this study is plate waste. The data collected in an experimental design was analysed to determine if there were statistically significant differences in the amount of plate waste between the intervention groups and the control groups. The data collected from both groups was compared using an ANOVA statistical analysis to determine if there was a significant difference in plate waste between the control and experimental groups.

4. Results

4.1. Descriptives

The transactions conducted are presented in Table 1.

Table 1
Descriptives

Variable	Category	Number of transactions	Percentage
Plate waste composition		400	100
Portion size reduction	Experimental group	200	50
	Control group	200	50
Total		400	100
Price-per-weight	Experimental group	200	50
	Control group	200	50
Total		400	100
Variety of meal items	Experimental group	200	50
	Control group	200	50
Total		400	100

Four hundred transactions were recorded in the initial study to determine the meal components that contributed most to plate waste. Four hundred transactions were observed and recorded for each intervention strategy: portion size reduction, price-per-weight, and variety of menu items.

4.2. Hypotheses testing

The first hypothesis stated that each meal component has differential levels of plate waste. A one-way between-subjects ANOVA was run with meal component as the independent variable and plate waste as the dependent variable, and the results are shown in Tables 2, 3 and 4.

Table 2
Descriptives for meal components

Meal component	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Starch	400	18.78	15.06	.75	17.2989	20.2601
Protein	400	1.68	2.98	.15	1.3892	1.9758
Vegetables	400	3.29	5.14	.26	2.7794	3.7906
Total	1200	7.92	12.11	.35	7.2295	8.6018

Table 3
ANOVA results for meal components

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	71327.326	2	35663.663	407.973	.000
Within Groups	104637.866	1197	87.417		
Total	175965.192	1199			

Table 4
Multiple Comparisons

Dependent Variable: Plate waste						
(I) Meal component	(J) Meal component	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Starch	Protein	17.10*	.66	.000	15.5121	18.6819
	Vegetables	15.49*	.66	.000	13.9096	17.0794

Table 4 ***(continued)***

Protein	Starch	-17.10*	.66	.000	-18.6819	-15.5121
	Vegetables	-1.60*	.66	.047	-3.1874	-.0176
Vegetables	Starch	-15.49*	.66	.000	-17.0794	-13.9096
	Protein	1.60*	.66	.047	.0176	3.1874

*The mean difference is significant at the 0.05 level.

The results indicated that various meal components such as starch (M = 18.78; SD = 15.06), protein (M = 1.68; SD = 2.98), and vegetables (M = 3.29; SD = 5.14) have differential levels of plate waste as a percentage of the food served, F (2, 1197) = 407.903, p < .001. A post-hock test using the Bonferroni method indicated that the pairs for all the possible combinations had significant differences. Since the results of ANOVA showed an essential difference between plate waste of various meal components and starch waste, which proved to be the highest contributor to food waste, the study assessed the different interventions to reduce waste on that particular contributor of food waste.

A series of ANOVA tests were used to compare the mean plate waste for the experimental group (portion size reduction) (n=200) and the control group (n=200), the mean plate waste for the experimental group (price-per-weight) (n=200) and the control group (n=200), and the mean plate waste for the experimental group (meal variety) (n=200) and the control group (n=200). The results are shown in Tables 5 and 6.

Table 5
Descriptives for intervention strategies

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
Portion size reduction	Control	200	30.27	11.83	.83	28.63	31.92
	Intervention	200	4.25	6.17	.44	3.38	5.11
	Total	400	17.26	16.08	.80	15.68	18.84
Price per weight	Control	200	33.81	9.15	.65	32.53	35.08
	Intervention	200	4.14	4.97	.35	3.45	4.84
	Total	400	18.97	16.57	.83	17.35	20.60
Meal variety	Control	200	34.63	8.99	.64	33.37	35.88
	Intervention	200	4.28	6.27	.44	3.41	5.16
	Total	400	19.45	17.05	.85	17.78	21.13

Table 6
ANOVA results for intervention strategies

		Sum of Squares	Df	Mean Square	F	Sig.
Portion size reduction	Between Groups	67753.487	1	67753.487	761.121	.000
	Within Groups	35429.175	398	89.018		
	Total	103182.662	399			
Price per weight	Between Groups	87989.357	1	87989.357	1621.485	.000
	Within Groups	21597.343	398	54.265		
	Total	109586.700	399			
Meal variety	Between Groups	92075.834	1	92075.834	1533.472	.000
	Within Groups	23897.522	398	60.044		
	Total	115973.355	399			

An ANOVA test for portion size reduction strategy was statistically significant, with the mean score for the experimental group (M = 4.25; SD = 6.17) being significantly lower than that of the control group (M = 30.27; SD = 11.83), F (1, 398) = 761.121, p < 0.001. An ANOVA test for the pat-per-weight strategy was statistically significant, with the mean score for the experimental group (M = 4.14; SD = 4.97) being

significantly lower that of the control group (M = 33.81, SD = 9.15), F (1, 398) = 1621.485, p < 0.001. Finally, an ANOVA test for the meal variety strategy was also statistically significant, with the mean score for the experimental group (M = 4.28; SD = 6.27) being significantly lower than that of the control group (M = 34.63, SD = 8.99), F (398) = 1533.472, p < 0.001.

Having established that all three interventions assessed had some efficacy in reducing plate waste, the study went on to rank the effectiveness of the three selected interventions. Before ranking the interventions, the study sought to determine whether the three interventions had differential efficacy. An ANOVA test was run, and the results are presented in Table 7.

Table 7
ANOVA

Plate waste					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	2.061	2	1.031	.030	.970
Within Groups	20324.567	597	34.045		
Total	20326.628	599			

ANOVA results showed no significant differences between the three plate waste intervention strategies, F (2, 597) =.30, p = .970.

5. Discussion

The results revealed that the most wasted meal component is starch. Starch is prepared from mealie-meal, which, in turn, is a product made from maize. Maize is one of the cheapest cereals in the world and, therefore, does not cost much to the patrons. As a result, the starch plate waste component constitutes a higher proportion of plate waste. The results align well with previous research, where starch was the most common meal component discarded, especially when served in more significant portions (Birch et al., 2007).

Vegetables were the second most common component of plate waste. Vegetables are another meal component that is less expensive and could easily get wasted. This is particularly the case where vegetables are either poorly cooked or are served in abundance (Birch et al., 2007).

There was virtually little waste from the meat meal component. Meat is one of the components of delicious meals that is scarcely available in poor developing countries such as Zimbabwe. It is the most expensive component of a meal, contributing a more significant portion of the meal cost. It is rarely served in abundance, making it almost impossible for the patrons to waste it. However, plate waste for meat is still prevalent in poorly cooked meals (de Boer et al., 2014).

Having identified starch as the highest contributor to plate waste, the study proceeds to assess the efficacy of the selected intervention strategies for reducing plate waste for starch. The first intervention strategy was reducing portion size. The reduction in portion size substantially led to a decrease in plate waste. The portion size reduction strategy is particularly appealing to the caterers for not adversely affecting the levels of patrons' satisfaction (Dhir et al., 2020). The findings in this study added some empirical weight to a host of previous research, such as the one by Ravandi & Jovanovic (2019) that recorded a 30% reduction in plate waste due to portion size reduction.

The second strategy involved introducing the pay-per-weight strategy. The pay-per-weight strategy significantly led to the reduction in plate waste. Previous research has indicated that patrons feel guilty about wasting some portions of the food they have paid for (Zuraikat, 2018; Stancu et al., 2016). Thus, through this strategy, patrons are likely to feel as if they are directly wasting their financial resources by indulging in plate waste (Zuraikat, 2018), and this enhances environmental consciousness (Fuchs, 2023).

The third and last strategy involved increasing meal choices. The increased meal choices strategy also significantly led to plate waste reduction. This can be accounted for by the fact that patrons tend to maximise the benefits from a wide range of choices. A previous study by Visschers et al. (2020) explained that meal variety led to patrons getting the correct meal type, which may minimise wastage. The results indicated an equivalent efficacy among the three studied plate waste reduction interventions. Therefore, food service industry practitioners can choose from either of the interventions based on operational viability and market conditions.

6. Conclusions and theoretical contributions

In conclusion, the nudge theory provides a theoretical contribution to appreciating how minor variations in a situation can result in substantial behavioural changes. Reducing food portion sizes, implementing price-per-weight, and increasing meal variety are effective ways of achieving less waste. Additionally, since most previous studies on plate waste were conducted in developed countries (Dhir et al., 2020), this study validated previous research findings on the selected plate waste reduction intervention strategies using samples from a developing country. Moreover, most earlier research dealt with plate waste reduction strategies not grounded in theory. This study worked with theory-driven hypotheses using the nudge theory. All three hypotheses supported by the research validated the predictive power of the nudge theory.

7. Recommendations, policy implications and limitations

To reduce plate waste, the study recommended the adoption of the interventions tested in this study. These interventions involved implementing the reduced portion size, pay-per-weight, and providing meal varieties. These interventions were effective in lowering plate waste from cafeterias at public institutions. These recommendations can be codified as a statutory instrument in the short run and an act of parliament in the long run. Alternatively, the Environmental Management Act of 34 06 2017 can be amended to incorporate clauses related to the reduced portion size, pay-per-weight, and variety of meals.

The findings about the interventions' efficacy are not easily transferrable to other food service establishments since a cafeteria system offers a more functional than a hedonic service. This scenario differs from other food service establishments such as casual, limited-service, fine-dining, and quick-service restaurants where pleasure is part of the service package. This poses a significant limitation in terms of external validity. Future studies should replicate this study in other food service settings, such as full-service, take-away, and fast-food restaurants.

The quasi-experimental design outlined above helped to determine whether various interventions lead to plate waste reduction. However, it is essential to note that other factors, such as hunger levels, taste preferences, and environmental factors, may influence plate waste. Therefore, future research studies must control for these other extraneous variables to attain some internal validity.

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