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Marketing Green Fertilizers: Insights into Consumer Preferences

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Abstract: In an effort to support the long-term viability of the bioenergy industry through an end market for digestate, we investigated purchasing preferences for fertilizer product features in the home gardening market. We conducted a discrete choice experiment (DCE), presenting 504 respondents with a total of 6048 product attribute choices in a simulated context that replicated the tradeoff decisions made in the real marketplace. We analyzed the choice data using a hierarchical Bayes estimate to generate part-worth utilities for fertilizer product attributes. We then conducted a latent class analysis to identify market segments that could be expected to respond to differentiated product design strategies. We were able to quantify both purchasing preferences for fertilizer product attributes as well as the importance of each attribute to the perceived utility of a product. We were further able to identify five distinct market segments that make clear the potential for differentiated strategies in the home gardening market. We found both negative and positive price sensitivities, with sociodemographically distinct subgroups that favored low-, mid-, and high-priced products. We also found purchasing preferences for brand status, product labeling and nutrient values. Our results provide insights that should help product managers in the biogas industry develop marketing strategies to integrate digestate into a sustainable energy production system.

Keywords: green fertilizer marketing; biogas digestate; private gardeners; discrete choice experiment

1. Introduction

Few would question that progress towards making societies more sustainable depends on consumer choices. While green energy and transportation choices plainly contribute to a more resource-efficient society, less obvious may be how choices in another area—the household garden—can contribute to an ecologically sustainable future. Yet the soil amendment and fertilizer choices made by private gardeners form key links in a chain of production processes, and these processes carry significant environmental consequences.

Many gardens are over-fertilized, and this contributes both to greenhouse gas emissions and phreatic water contamination [1–6]. The most important of these are nitrogen (N), phosphorus (P) and potassium (K) [7–9], and the production of each consumes energy and contributes to climate change. Nitrogen production relies on ammonia as a raw material; the production of ammonia generally proceeds through the Haber-Bosch manufacturing process, an energy-intensive nitrogen-fixation

process that accounts for 1.2% of global energy consumption [10,11]. Phosphorus and potassium, on the other hand, are obtained through mining [12,13]. Phosphorous production relies heavily on limited and nonrenewable mineral resources, making it the subject of extensive scrutiny by environmental scientists [8,11,14,15]. The phosphorous production chain is all the more fragile because 77% of the world's phosphate reserves are concentrated in just one country: Morocco [9,16,17]. That is decidedly not the case with potassium fertilizers, which are mined and produced in many parts of the world. However, though potassium itself may pose limited environmental risks, the mining activities involved in the extraction of phosphate rock and potash can cause extensive and long-lasting damage to the environment.

Seeking to minimize the environmental impacts of mineral fertilizers, researchers have proposed the use of organic alternatives [2]. One of the well-known alternatives is biogas digestate [18–22]—the term "digestate" refers to the nutrient-rich residue from the anaerobic fermentation process used in biogas production. Though every biogas plant (currently 17,240 in Europe, with 10,786 of those in Germany) produces digestate, it often cannot be applied locally due to high regional nutrient surpluses and legal restrictions.

An obvious approach to maximizing the value of digestate to a cleaner production system would be to transport the digestate to arable farming regions with pressing nutrient demand. Numerous researchers have examined means of facilitating this approach [23–25], including upgrading solid digestate so it can be transported at reasonable cost and utilized in both agricultural and non-agricultural sectors [26,27]. But implementing cleaner digestate-based fertilizer production systems faces obstacles, meaning the economic and ecological benefits of using digestate remain largely unrealized [28]. Obstacles include the legal status of digestate-based products [28,29], as well as socioeconomic challenges [30]. The private gardening sector, however, shows considerable potential for integrating biogas digestate-based products in soil amendments [31]. Still, such integration demands that digestate producers apply innovation and creativity to overcoming current obstacles; it demands that they create fertilizer products able to compete successfully in the consumer market. To do so, producers need to understand the purchasing behavior of their target consumers.

To that end, this study examines the fertilizer purchasing preferences of private gardeners. We use a discrete choice experiment to analyze how different product attributes play into consumer decisions; we further evaluate the importance of these attributes to different segments of the non-agricultural consumer market. Through such analyses emerge strategies for integrating digestate-based products into the already mature market for soil amendments. We expect these strategies to contribute to the design decisions of all soil amendment marketers, but in particular to those product managers in the biogas and livestock sector. The more these managers can create a profitable market for digestate-based products, the better they will be able to recycle their nutrient surpluses and the sounder will be the footing on which the biogas industry can stand [31–34].

2. Material and Methods

2.1. Consumer Research and Discrete Choice Experiments

We elected to research consumer fertilizer purchasing preferences through a discrete choice experiment (DCE) administered by an online questionnaire. DCEs have gained widespread acceptance in recent years as a sophisticated tool for eliciting consumer preferences for products or services. In such experiments, products are characterized by a set of attributes (e.g., color and cost) and attribute levels (e.g., green, red, blue and prices); the combination of attributes at specific levels comprises the perceived utility of a good [35]. In contrast to simpler survey methods, a DCE approach presents consumers with decisions that more closely reflect those made in realistic tradeoff situations. That allows researchers to gain insight into real purchasing preferences.

This approach was originally developed by [36,37] for marketing and transportation research, but its ability to more faithfully capture realistic decision-making scenarios has made it applicable

throughout social science. Whether used to evaluate customer preferences for electricity or food products [38–44], or contracts in the agricultural sector [44–47], or even conservation services and natural resources [48–52], the discrete choice approach has led to valuable insights into how decisions are made in the real world.

The validity of discrete choice experiments rests on well-tested random utility theory (RUT) [53]. First introduced by [54] and further developed in by [55–57], random utility theory models consumer preferences in an intuitively elegant manner: it assumes consumers make choices based on the utility benefits they gain from the various product attributes. These choices emerge under the influence of two factors: one rationally explicable and a second inexplicable. That is [53,58,59]:

$$U_{in} = V_{in} + \varepsilon_{in}$$

where U_{in} is the unobservable (latent) utility U, that an individual i associates with a given choice n. This utility consists of an explainable component, V_{in}, as well as a random and unexplainable component ε_{in} associated with the consumer choice [53].

2.2. Experimental Design

In selecting relevant product attributes and attribute levels for our experimental design, we sought to replicate the real-world choices consumers face in making purchasing decisions. We started with a systematic qualitative process, which is crucial for a valid DCE design [60]. We conducted 20 interviews with private gardeners, recording each for later transcription. Transcripts were analyzed using the qualitative data analysis software MAXQDA. From this analysis, we identified the product attributes of relevance to most gardeners. We then created questions for an online survey based on these attributes and those levels readily available in German garden stores. This led to the configuration options listed in Table 1.

Table 1. Fertilizer attributes and their respective levels.

Attribute	Attribute Levels
Fertilizer type	• Universal (general-purpose) fertilizer • Flower (specific purpose) fertilizer
Brand name	• Premium brands (e.g., Compo, Neudorff) • Middle class brands (e.g., Gartenkrone, Flora Self) • Private labels of garden stores (e.g., Obi, Toom)
Label	• Not labeled • Labeled as "Organic"
Nutrient values (NPK level)	• 4-2-3 • 8-6-7 • 10-12-11
Resource (raw material)	• Organic • Mineral
Price (2.5 kg package)	• €6 • €9 • €12

We choose to associate the resource attribute, i.e., the raw material from which the fertilizer is made, with the values "organic" or "mineral", refraining from explicit use of the term "digestate". As we know of no product in the market explicitly labeled as digestate, this choice mirrors current offerings. It further allows our results to be transferred to products derived from other organic materials such as manure or bone meal. In our fertilizer DCE, an orthogonal fractional factorial design was applied and was part of a larger survey. It further encompassed a DCE on potting soil, aspects of

the gardeners purchasing behavior, their risk perception as well as their attitude towards renewable and resources. In this paper we focus on the results of the fertilizer DCE. The Sawtooth Software is using a complete enumerated algorithm and resulted in 100 different blocks of which 12 were shown to each respondent in the survey. Each block contains 3 product options as well as an opt-out option to choose from.

2.3. Data Collection and Analysis

The survey was conducted in collaboration with the market research institute TNS Deutschland GmbH. The respondents were recruited from an online panel that contains 160,000 members in total. All participants were rewarded in cash or through vouchers.

Data collection took place from March through April 2016. This period was chosen for two reasons. First, it represented the start of the gardening season, when suppliers launch their advertising campaigns for soil amendment products. Second, extending over the Easter holidays, this period was thought to offer respondents more time to complete the survey, meaning we could expect a good response rate and a high degree of engagement in the survey questions. Acceptance criteria for respondents included:

- must live in a house or apartment;
- must be at least 18 years old;
- must have purchased a garden fertilizer within the last three years.

Only gardeners who met all three criteria were allowed to complete the survey.

In total 1456 gardeners were asked to complete the survey ether containing the fertilizer or the potting soil DCE. 507 gardeners completed potting soil DCE and 445 did not buy any soil amendments such as fertilizers and potting soil or did not complete the survey.

In total, 504 respondents qualified and completed the fertilizer DCE. Respondents were each asked to complete 12 conjoint discrete choice questions. Hence, a total of 6048 choices were available for analysis.

By independently varying the attributes shown to the respondents and collecting their responses to the different product profiles, we could statistically deduce what product features were most desired and which attributes made the most impact on choice. This gave us a full set of preference scores (often called part-worth utilities) for each attribute level included in the study. Our statistical approach used a two-level hierarchical Bayesian model to estimate part-worth utilities at the individual level [61,62]. In this model, the upper level operated under the assumption that part-worth utilities were characterized by a single multivariate normal distribution. At the lower level, the multinomial logit model governed the probability of choosing one alternative over another.

The individual part-worth utilities so obtained were further used to segment the respondent sample into groups with similar purchasing preferences. Segmentation proceeded using the latent class (LC) method. This approach can reveal details about the market's structure and so improve the results derived from a discrete choice experiment [61].

2.4. Selection of Sociodemographic Variables

To analyze the characteristics of different consumer groups, we collected data on a number of sociodemographic variables. We also queried the respondents about their gardening practices. The parameters of interest are listed in Table 2.

Table 2. Sociodemographic Variables and Gardening Questions (standard deviations in parentheses).

	Mean	Minimum	Maximum
Sociodemographic Characteristics			
● Age in years	52.32 (13.06)	18	81
● Gender (female in %)	44%		
● Number of individuals living in the household	2.63 (1.01)	1	5
● Level of income (total monthly net income): 1 = under €1000, 2 = €1000–€1999, 3 = €2000–€2999, 4 = €3000–€3999, 5 = €4000–€4999, 6 = €5000 and over	3.88 (1.52)	1	6
● Level of education: 1 = no formal education 2 = still attending school/vocational training, 3 = finished vocational training 4 = master craftsman training/vocational school 5 = Degree in applied sciences 6 = University degree, PhD	3.88 (1.21)	1	6
Gardening Questions			
● Kind of fertilizer for outdoor use (not potted); from 1 to 5 with 1 = exclusively solid 5 = exclusively liquid	2.13 (0.87)	1	5
● Kind of fertilizer for potted plants; from 1 to 5 with 1 = exclusively solid 5 = exclusively liquid	2.98 (1.03)	1	5
● I am certain the fertilizer I buy fits my plant's needs; from 1 to 6 with 1 = strongly disagree 6 = strongly agree	4.28 (1.13)	1	6
● Fertilizer is needed to promote plant growth; from 1 to 6 with 1 = strongly disagree 6 = strongly agree	4.96 (0.88)	1	6
● Gardening is an important hobby for me; from 1 to 6 with 1 = strongly disagree 6 = strongly agree	4.59 (1.29)	1	6

3. Results

Overall, the majority of our respondents (92.7%) purchase fertilizers from brick-and-mortar businesses; only 13.9% purchase products online, while 1.6% have products delivered to their homes (respondents could select more than one answer, hence percentages sum to values greater than 100). Of the brick-and-mortar purchases, 80.8% were made in do-it-yourself (DIY) stores, 18.5% in plant nurseries, and 17.3% in supermarkets. Asked how they made their decisions, 71% of the respondents said independently; 28% were supported by their partner, children, sales consultants or others.

3.1. Hierarchical Bayes Estimation

Table 3 lists the estimated mean utility values for the hierarchical Bayes (HB) model.

Table 3. Mean utility values of the hierarchical Bayes (HB) model.

Attribute	Level	HB Est. Results
Fertilizer type	Universal fertilizer	4.0
	Flower fertilizer	−4.0
Brand name	Premium brand	20.9 ***
	Middle class brand	−14.5 **
	Private label brand	−6.4
Label	Not labeled	−17.9 ***
	Organically labeled	17.9 ***
Nutrient values	NPK values (4-2-3)	−21.7 ***
	NPK values (8-6-7)	8.5 **
	NPK values (12-10-11)	13.2 ***
Resource	Organic (fertilizer)	10.4 *
	Mineral (fertilizer)	−10.4 *
Price	€6	60.0 ***
	€9	39.7 ***
	€12	−99.7 ***
McFadden pseudo *R*-squared (Percent certainty)		0.63
Root Likelihood (RLH)		0.60
Average Variance		3.53
Parameter RMS (root mean square)		2.35

***, **, * indicate significance at the 0.1%, 1%, and 5% levels respectively.

The utility values convey the importance of the particular attribute level to the overall utility of the product. These values were available for each respondent, but are presented here as mean values to capture significant trends. Values are expressed as zero-centered part-worth differences, meaning the utiles for levels within one attribute are rescaled so they sum to zero. Values close to zero denote uncertainty in respondents' evaluation of that particular attribute level. Larger values reveal stronger coherence between perceived utility and the attribute level [63]. Positive values contribute to greater utility of the product and negative values to lesser utility in the eyes of the consumer. The willingness to pay (wtp) is often calculated with this regard; however, it creates inflated values and distorts the results and even new features in DCE have been proposed to improve the wtp estimates [64–69].

As shown in Table 1, the findings for almost all attribute levels are statistically significant at the *p*-values indicated. For example, these results demonstrate that labeling a fertilizer as organic adds to the perceived utility of the product, so contributes to its purchase; the absence of a label detracts from a product's perceived utility, making its purchase less attractive. Both statements are significant at the *p* = 0.001 level. At *p* = 0.05, results demonstrate that respondents favored a fertilizer made from organic resources over a mineral-based fertilizer. At *p* = 0.01 or better, the higher the NPK levels in the fertilizer (at least across the three levels studied), the greater the perceived utility of the product. Statistical significance, however, is not undisputed and should not be confused with the economic significance [70–72].

Table 4 lists the attribute importance scores for the whole sample.

These attribute values are expressed as percent of the whole and so sum to 100%. They capture the degree to which each attribute factors into the consumer's purchasing decision. These can be, and should be, compared across attributes, so it is fair to say that considering the respondents as a whole, price plays the most important role in their purchasing decisions. The quality connoted by the brand name ranks second, while the raw material used to produce the fertilizer plays the least important role.

Table 4. Attribute importance scores.

Attributes	Importance Scores
Fertilizer type	13%
Brand name	19%
Label	9%
Nutrient values	11%
Resource	8%
Price	40%

3.2. Latent Class Analysis

As discussed in Section 2.3, individual part-worth utilities permit segmentation of the respondent sample into subgroups with similar purchasing preferences. Identifying subgroups means discovering statistically significant heterogeneity in respondent choice data. Should such exist, segment-level part-worths can provide product designers with the insight they need to tailor their offerings to the preferences of specific customer groups.

To determine the extent of heterogeneity in the choice data, we applied latent class analysis [64], evaluating the following goodness-of-fit indicators:

(1) McFadden pseudo *R*-squared (percent certainty)
(2) Consistent Akaike information criterion (CAIC)
(3) Chi-square (chi sq)
(4) Relative chi-square (rel chi sq)

A summary of these indicators is displayed in Table 5, for group sizes varying from two to six.

Table 5. Best Replications for latent class analysis.

Groups	Percent Certainty	CAIC	Chi Sq	Rel Chi Sq
2	21.66	13,340.24	3632.24	172.96
3	26.26	12,675.01	4404.25	137.63
4	29.14	12,300.00	4886.04	113.63
5	30.82	12,124.63	5168.19	95.71
6	32.32	11,980.13	5627.26	74.04

In general, the higher the values for percent certainty, consistent Akaike information criterion, and chi-square, the better the model fit. The lower the values of the relative chi-square, the better the fit. We decided, however, to choose the model with five groups rather than six. We judged six to represent excessive compartmentalization, inasmuch as five sufficed to capture distinct purchasing preference profiles. Mean utility values for these five profiles were then generated using the method described in Section 3.1, producing the values in Table 6.

The results clearly show heterogeneity in the respondents and their differentiated emphases on attributes and their levels; we have sought to capture this in the naming of each group. The universal product buyer emerges as the consumer who strongly prefers a general purpose fertilizer over one designated for a particular plant. The price sensitive and price sensitive green buyers show strong preference for low priced products, and so favor private label, i.e., inexpensive, brands. The price sensitive buyers are differentiated by one group's strong preference for an organic label (hence "green") and the other's near indifference to the labeling.

Table 6. HB mean utility values for five segments.

	Group 1	Group 2	Group 3	Group 4	Group 5
	Universal Product Buyer	**Price Sensitive Green Buyer**	**Price Sensitive Buyer**	**Multi Criteria Buyer**	**Premium Product Buyer**
	n = 53	*n* = 36	*n* = 96	*n* = 273	*n* = 46
Fertilizer Type					
Universal fertilizer	101.9	2.0	−6.2	−37.1	10.0
Flower fertilizer	−101.9	−2.0	6.2	37.1	−10.0
Brand Name					
Premium brand	20.1	−15.4	−21.5	22.6	176.9
Middle class brand	−20.9	−4.2	5.0	−28.9	−76.4
Private label brand	0.8	19.6	16.4	6.2	−100.6
Label					
Not labeled	−35.0	−57.3	2.8	−54.0	38.5
Organically labeled	35.0	57.3	−2.8	54.0	−38.5
Nutrient Values					
NPK values (4-2-3)	−33.5	−19.5	−14.9	−45.9	−6.9
NPK values (8-6-7)	16.1	15.2	28.1	0.2	18.1
NPK values (12-10-11)	17.4	4.3	−13.2	45.7	−11.2
Resource					
Organic (fertilizer)	−10.9	−3.6	11.2	19.4	41.2
Mineral (fertilizer)	10.9	3.6	−11.2	−19.4	−41.2
Price					
€6	98.7	196.1	230.6	14.8	−69.5
€9	15.1	12.5	17.7	110.6	25.2
€12	−113.8	−208.6	−248.3	−125.3	44.3

The multi-criteria buyer makes up the largest group and represents the majority of the sample. This purchasing profile shows preferences in all the attributes tested. Mid-priced but carrying a premium brand, special-purpose, labeled organic and from organic sources (and of special note, offering higher nutrient (NPK) values): that is the product profile preferred by the multi-criteria buyer.

Premium product buyers show their strongest preference for the premium brand and correspondingly for the higher-priced product. Of all the groups, they show the strongest preference for organic-based fertilizers, but curiously respond negatively to organic labeling. Their NPK preference is for a medium level nutrient content. These buyers' strong preference for organic-based fertilizers and willingness to pay a premium price bodes well for digestate-based and other renewable fertilizer producers, but their curious response to organic labeling suggests they may be skeptical towards some certification schemes [73,74]. Hence, validating and overcoming such skepticism may represent a distinct opportunity for marketing to the premium buyer.

We also computed the importance of each attribute for the purchasing decisions made by buyers in the five groups; these are shown in Table 7.

Please note that these importance scores only show the weighting given to each attribute in a purchasing decision; they do not convey information about which level is preferred for a given attribute. So, for example, although Group 1 and Group 4 both show sensitivity to fertilizer type, Group 1's preference is for a general-purpose fertilizer, while Group 4's is for a special purpose product.

This table illustrates that the premium product buyer—making up almost 10% of the respondents (46 out of 504)—weighs brand name heavily in making a purchasing decision, while putting roughly the same utility value on price as on the resource used to make the product. All the other groups rank price as the most important attribute in making a purchasing decision. For Group 1, fertilizer type factors into the decision almost as much as price.

Table 7. Attribute importance scores for five segments.

	Group 1	Group 2	Group 3	Group 4	Group 5
	Universal Product Buyer	Price Sensitive Green Buyer	Price Sensitive Buyer	Multi Criteria Buyer	Premium Product Buyer
	n = 53	*n* = 36	*n* = 96	*n* = 273	*n* = 46
Fertilizer type	34%	1%	2%	12%	3%
Brand name	7%	6%	6%	9%	46%
Label	12%	19%	1%	18%	13%
Nutrient values	8%	6%	7%	15%	5%
Resource	4%	1%	4%	6%	14%
Price	35%	67%	80%	39%	19%

3.3. Sociodemographic Characteristics of Groups

Our final set of results focuses on the sociodemographic characteristics and gardening practices of the subgroups identified in Section 3.2. Table 8 presents the mean values and standard deviations of these descriptive statistics. Please remember that this data represents only gardeners who have previously purchased soil amendments.

Table 8. Sociodemographic characteristics of the sample (standard deviations in parentheses).

	Group 1	Group 2	Group 3	Group 4	Group 5
	Universal Product Buyer	Price Sensitive Green Buyer	Price Sensitive Buyer	Multi Criteria Buyer	Premium Product Buyer
	n = 53	*n* = 36	*n* = 96	*n* = 273	*n* = 46
Sociodemographic Characteristics					
Average Age of respondents (years)	52.06 (12.42)	57.25 (10.34)	53.14 (13.08)	51.47 (13.78)	52.11 (10.59)
Gender (female in %)	49%	36%	44%	44%	48%
Household size	2.77 (1.15)	2.42 (0.91)	2.51 (1.14)	2.68 (1.07)	2.57 (1.09)
Level of income	4.02 (1.50)	3.78 (1.55)	3.67 (1.61)	3.92 (1.53)	4.02 (1.26)
Level of education	3.98 (1.34)	3.64 (1.15)	3.89 (1.35)	3.86 (1.15)	4.09 (1.15)
Gardening Questions					
Kind of fertilizer for outdoor use (not potted)	1.94 (0.79)	2.08 (0.97)	1.99 (0.96)	2.21 (0.85)	2.17 (0.74)
Kind of fertilizer for potted plants	2.68 (1.06)	2.94 (1.16)	3.11 (1.17)	3.00 (0.97)	2.98 (0.95)
Certainty about product fitting plant needs	3.79 (1.23)	4.03 (1.18)	3.89 (1.08)	4.43 (1.09)	4.96 (1.01)
Fertilizer is needed to promote plant growth	4.94 (0.85)	4.68 (0.88)	4.79 (0.94)	5.02 (0.82)	5.37 (0.68)
Gardening is an important hobby for me	4.19 (1.34)	4.43 (1.44)	4.25 (1.29)	4.72 (1.22)	5.11 (1.22)

Heterogeneity is again evident in this data, and a number of differences emerge that may help explain observed preference profiles. For example, premium product buyers have both the highest level of income and the highest level of education. Being willing to pay the highest price on average, these buyers also show the greatest certainty in having bought the product that best suits their needs. They also score highest in ranking gardening as an important leisure activity. This may explain why they, more than other buyers, perceive the need for fertilizers to promote plant growth.

On the other hand, buyers in the two price sensitive groups have on average the lowest level of income, so their preference for inexpensive products reflects their income status. Purchasing less expensive products, these buyers also face greater uncertainty about having purchased the right product to meet their garden's needs.

4. Discussion

We have sought to provide insights that will help product managers in the biogas industry create digestate-based fertilizer products for the home gardener market, and in so doing bolster both the ecological and economic viability of this promising industry. We designed a discrete choice experiment that presented respondents with varying arrays of fertilizer product attributes and attribute levels, then asked respondents to make purchasing choices where they had to evaluate tradeoffs like those found in the real marketplace. We collected choice data from 504 respondents who made a total of

6048 purchasing decisions. We subjected the choice data to conjoint analysis, and this allowed us to quantify both purchasing preferences for fertilizer product attributes as well as the importance of each attribute to the overall utility of a product.

How best to apply our results to the design of strategies for soil amendment markets depends on the degree of integration, both vertical and horizontal, biogas facility operators and the biogas industry achieves. Absent any integration, a single biogas operator can individually create and market a garden fertilizer. This involves not only production of the digestate, which the operator currently does but typically only to a raw level, but also further digestate processing as well as developing the products, the product packaging, the communication strategies and the distribution channels needed to successfully market the product. The operator would not likely enjoy economies of scale, since the facility would be marketing a relatively small amount of organic fertilizer. However, an operator following this course would have the advantage of being able to build a loyal, perhaps predominantly local, customer base and so obtain relatively high prices.

Taking steps toward horizontal integration in the industry, digestate producers could jointly create a brand and establish distribution channels for their products. This would enable economies of scale and facilitate the marketing of larger amounts of organic fertilizer and thus allow for greater product differentiation. This option could also support distribution into DIY stores that demand large quantities and a range of products. This option would give biogas operators greater marketing power while allowing them to remain independent from intermediaries. Clearly, however, plant operators with individual interests would have to work cooperatively to develop a market for their digestate products.

A third option entails vertical integration into the existing production system operated by larger fertilizer manufacturers and distributors. This would allow for the classic division of labor whereby the biogas plant operator focuses on producing high quality digestate for an integrated production system that distributes processing and marketing across multiple levels of a supply chain. This approach has the advantage that all participants can focus on their core competencies and already established fertilizer marketers can integrate digestate into their existing product offerings. The drawback of this option is that plant operators and their products would be replaceable. A single biogas plant would be merely one of many digestate suppliers, so the bulk buyer would have great leverage on the setting of price. This option, however, does allow the plant operator to manage and market the occurring digestate in a lean and resource efficient way [35].

Each level of integration offers a different opportunity for leveraging the purchasing preference results found in this study. Single biogas operators with limited resources and smaller product quantities are unlikely to have the capacity to satisfy the entire spectrum of customer preferences found in our latent class analysis. Assuming they could design and market only one product, they could target either the most common consumer group—the multi-criteria buyer—or one of the more specialized groups. The mean utility values for the hierarchical Bayes model could then guide their design decisions. Aiming for the multi-criteria buyer, a producer would create a mid-priced, special-purpose product, labeled organic and from organic sources and offering higher NPK values. However, the operator would also need to establish premium status for the facility's brand to fully accommodate this buyer. Should the operator instead focus on a smaller, more specialized customer segment, targeting the premium product buyer would seem a sensible decision, as they exercise the greatest purchasing power and willingness to pay. However, to reach these buyers, the operator would have to work much harder to establish premium status for the facility's brand, since this is the predominant attribute that attracts the affluent buyers for whom gardening is an essential leisure activity. Attaining such status on a national scale would likely exceed the means of a single biogas plant; however, the strategy could also work were the brand perceived as premium only in the mindsets of local buyers. A savvy operator could exploit local sensibilities to appeal to a localized concept of "premium".

Of course, these, considerations can just as easily motivate a group of integrated operators. But with larger digestate quantities and greater marketing resources, managers could design products

to focus on all five preference profiles found in this study. The greater the degree of integration, the greater the opportunity to fine-tune offerings to address specific market opportunities.

For all but perhaps the single operator, access to the distribution channels provided by DIY stores is key to mass market success. This does pose a challenge, however, since the large companies operating DIY stores have requirements that smaller operators may find difficult to meet. Operators not eager to do so could develop alternative channels through plant nurseries or the like. This might be a particularly promising approach to targeting the premium buyer, who would likely respond favorably to a more refined sales experience. Marketing to the premium buyer as though to a gardening connoisseur entails greater ingenuity and effort, but the rewards could be substantial.

From an ecological point of view, the fact that the majority of respondents display a "more-is-better" preference for high NPK values represents an opportunity for improved educational initiatives. Most home gardeners over-fertilize and more potted plants drown from excessive watering than die from too little. Over-fertilization leads to eutrophication of water bodies [75,76], and no home gardener wants to see his or her plants die. An educational concept like "What You Can Learn from a Green Thumb" could help home gardeners develop practices that were both ecologically more sound and personally more satisfying. Positioning digestate-based fertilizers as "green thumb friendly" fits this concept—because, with digestate as the sole raw material, mid-level NPK values are what can be expected. Otherwise, to achieve the double digit nutrient values that the multi-criteria buyer currently prefers, supplements would have to be added, which would further burden the production system.

5. Limitations and Further Research

We focused on the purchasing behavior of German gardeners towards fertilizer attributes. Other country studies might reveal different national preferences, just as studies have demonstrated nationally differentiated preferences for wood and food products [77,78]. This study also selected those product attributes common in the German market. Since many market players exist offering a wide range of products, only a limited range of these products and product attributes could be captured. Gardens vary extensively and their owners may focus on particular plants such as roses, rhododendron or box trees. Given the extremely wide variety of potential garden types, a differentiation of all potential alternatives would have been too complex for this experiment.

Further, although the discrete choice experiment (DCE) represents the most refined way of eliciting customer preferences, gaps concerning endogeneity have been outlined by [79,80]. Moreover, choices in a DCE depend heavily on the way a product is presented [81–83]. Product images of fertilizers should ideally be redesigned to better reflect the attribute options, but this would have entailed a much greater effort than we were able to expend. It can be expected that nicely designed product packaging (mostly premium brands) would have achieved higher scores.

Further research would do well to focus on the labeling and certification of soil amendments, for example on different quality labels. There are several labels in use; however, what they communicate is not as widely understood as for, say, food labels. A further research area to consider might be packaging design. Different sizes, materials and forms are available. Since sustainability continues to gain importance in many sectors, recyclable versus non-recyclable materials could be significant. A third target for future research would be to look closely at the final product itself. Although it often remains concealed until its application, a fertilizer can be marketed in different product forms (e.g., pellets, powder or granules), structures (liquid versus solid) and colors (e.g., blue, brown, grey, etc.), all of which are likely to elicit different preference responses. Other avenues of research remain open as well; the better consumer choices can be aligned with ecologically sound practices, the better our prospects for an environmentally cleaner future.

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