

Sentiment Analysis of β -Hydroxybutyrate (BHB) Supplements' Consumer Online Reviews

Ji Li^{1*}, Dan Lowe¹, Luke Wayment¹ and Qingrong Huang²

¹Nutraceutical Corporation, USA

²Food Science Department, Rutgers, the State University of New Jersey, USA

*Corresponding author: Agostinho G Rocha, Syneos Health, 301D College Road East, Princeton, NJ 08540, USA



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ABSTRACT

Background: Advanced approaches such as sentiment analysis have been developed to extract and analyze various objects for consumer insights. However, in the field of dietary supplement, we have scarcely observed such application which actually would help understand the consumer shopping behaviors on emerging supplement products. Thus, more attempts are needed to explore the consumer behavior via those new tools.

Methods: The text data of 71 β -Hydroxybutyrate (BHB) products' consumer reviews were extracted with the aid of the Web Scraper Chrome extension. Then, a lexicon-based sentiment analysis approach was developed to sort out the sentiment or polarity of BHB products' consumer online reviews. Word-level sentiment analysis gave direct observation of BHB products' consumer feedback, while sentence-level sentiment analysis further scored the analyzed text snippets with the labels of flavor and package. Besides, the compliment complex analysis helps verify the robustness of resultant analysis.

Results: We find that that flavoring is important to the β -Hydroxybutyrate (BHB) product performance among other factors such as packaging and brand. We also find that consumers are more willing to accepting flavored BHB products than unflavored BHB products despite of their high prices. Creativities such as lemon-raspberry flavor even differentiate the BHB sensory products among competitors. On the other side, high-volume packages provide us with more label space for product marketing and education. Appropriate product development ensures the basic functions of the active ingredients in products. In addition, brand building offers another layer of product differentiation.

Conclusion: A lexicon-based sentiment analysis is used to analyze the β -Hydroxybutyrate (BHB) products' consumer online reviews. Through the comprehensive text-mining, we concluded that appropriate flavoring could largely enhance the BHB products' market performance. High-volume packaging could further promote product marketing and education. Meanwhile, we cannot ignore factors such as active functions and brand building as well.

Introduction

β -Hydroxybutyrate (BHB) is the conjugate base of the organic compound hydroxybutyric acid. The ketone body BHB can be synthesized in the liver through a series of reactions during the metabolisms of fatty acids, ketogenic amino acids, and β -methylbutyrate. It is an essential carrier of energy from the liver to peripheral tissues during periods of long-time exercise, starvation, and lack of carbohydrates. BHB can also serve as an

energy source by our brain when blood glucose is low [1]. BHB compound functions interactively in our body. It can interact with inflammatory items in immune cells to decrease the level of inflammatory cytokines and further reduce inflammation [1]. Previous studies also demonstrated that BHB possessed the functions of stress reduction, [2] neural protection, [3] seizure alleviation, [4] weight loss, [5] and body metabolism in starvation [6].

Recognizing those functions, scientists spend efforts to commercialize BHB supplement products for the massive consumers. BHB products are currently commercialized more as weight loss and energy enhancer on the dietary supplement market. Thanks to their efforts, the consumers nowadays can easily get access to those products through channels such as retail stores, online platforms (e.g., Amazon), local clinics and comprehensive hospitals. BHB supplement is still a small-sized emerging market compared with traditional supplements such as vitamin C, whey protein, and etc. Further understanding consumers' BHB shopping behavior, especially online, provides us with first-hand consumer shopping data, guides R&D to design more targeted BHB supplement products or derivatives. In a broad sense, such study helps to develop cost-effective healthcare solutions for new product development.

The obtained consumers' online reviews served as the critical building blocks of this research piece. Based on those building blocks, sentiment analysis has been developed and applied to mine the text of consumer feedbacks. The technology of sentiment analysis is also found under terms such as emotion detection, [7] semantic analysis, [8] opinion mining [9] and etc. Those terms are more or less similar to the term "sentiment analysis" used here, a computational study of the text content of people's opinions, sentiments, emotions, and attitudes. In detail, it is regarded as a classification assignment as it classifies the orientation of a text into either positive, negative, neutral or compound [10] In the era of big data, it is useful for companies and individuals to monitor their reputation and get timely feedback about their products, activities, events, and policies [11]. It was also quoted as one of the hottest fields in computer science [11].

Both machine learning-based and lexicon-based approaches have been developed to realize the sentiment analysis of text data [12]. Machine learning-based analysis depends on large volume of data for accurate prediction. The more training data, the better the performance of the latter analysis. Meanwhile, lexicon-based approaches consult lexicons, the online or off-line dictionaries, to classify the polarities or emotional orientations. It relies on the consulting dictionary during which a fairly large number of data is good but not a must condition. The previous studies show that lexicon-based sentiment analysis work well on social media type text, [13] does not require large training data, and perform rapidly with streams of data [14]. For instance, Paltoglou and Thewall proposed their algorithm for unsupervised, lexicon-based sentiment analysis of web-based textual communication such as online discussions, tweets, and social network comments [13]. Under the wave of supervised, machine learning approaches in recent years, their results of extensive tests on three real-world datasets demonstrated that the developed algorithm outperformed machine learning solutions in the majority of cases. It suggested that lexicon-based sentiment analysis could be a robust and reliable approach to conduct sentiment analysis of informal communication on the internet. In another research, Kaushik and Mishra utilized

a Hadoop-based technique to carry out the sentimental analysis and opinion mining in a speedy and quantitative manner [14] Their results showed that the Hadoop-based method was a speedy and accurate technique ready for scaled data sets. Hence, amid the pool of different data analytical tools, sentiment analysis is suitable for analyzing the consumers' feedback on an emerging market with a rapid growth. Bearing such background, this paper illustrated the application of lexicon-based sentiment analysis to systematically analyze the consumers' online reviews on various BHB products, an emerging dietary supplement market. The resultant analysis helps us understand consumers' shopping behavior of innovative dietary supplements.

Methods

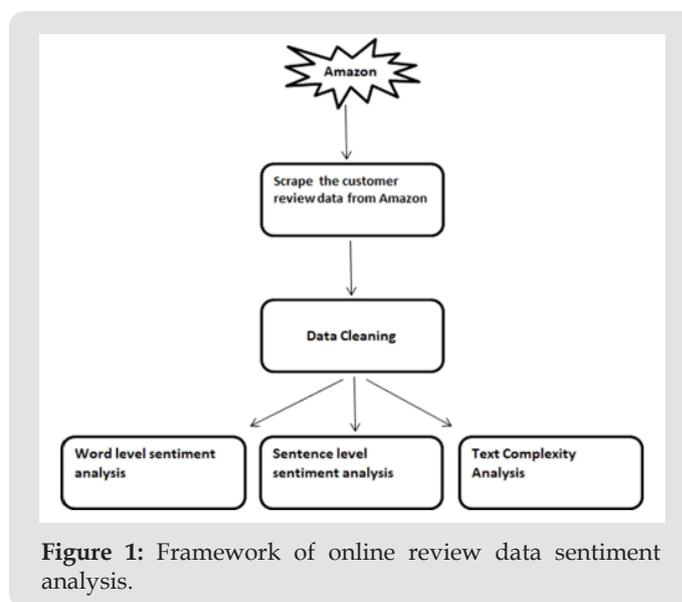


Figure 1: Framework of online review data sentiment analysis.

The framework of online reviews' sentiment analysis is displayed in Figure 1. It shows that the process of sentiment analysis including scraping the customer review data from Amazon.com, data cleaning, word-level sentiment analysis, sentence-level sentiment analysis, and text complexity analysis.

Online Review Scrape

The Web Scraper, a Chrome extension is used to extract reviews' texts from dynamic web pages. A sitemap that displays how the website should be traversed and what data should be extracted is created prior to online reviews' scrape. A series of JSON codes are developed and modified to scrape online customers' reviews from Amazon.com. The original code can be found in Scrapehero package on Github.com. The modified JSON code was inserted into the sitemap JSON box under Web Scraper extension before data collection. The request interval is set at 2000 ms during online review scrape. Depending on the complexity of the reviews, the reviews' scrape time for one product on Amazon varies from less than 1 minute to 30 minutes. Text data sometimes require pre-process or cleaning before text mining to minimize the noises or biases [10]. For the online reviews in this research, most users expressed their comments in a brief and straightforward way.

There are not many noise and uninformative parts as HTML tags, scripts and advertisements as other online texts [10]. We simply cleaned the text data by removing special characters and reorganizing the content for further analysis. On another side, we also tried maintaining the originality of the review contents as much as possible.

Word-level Sentiment Analysis

An external lexicon or dictionary served as resource to judge the text sentiment or polarity [15,16]. The words in online reviews of one product are obtained with NLTK tokenization before sentiment classification [17]. Then, they are classified into categories of positive and negative for further analysis. Besides, word clouds are generated based on the word-tokenized text contents with the wordcloud function in NLTK [17]. The word-level sentiment analysis gives us a direct observation of the sentiment expressed from the text comments.

Sentence-level Sentiment Analysis

Vader sentiment analysis of sentence-tokenized text of online reviews of one product is performed to gain sentiments including positive, negative, and polarity score [18]. This approach provides how positive or negative a snippet under analysis is. In details, the sentence-level snippets are then classified into the categories of positive, negative, neutral, and compound, during which scores are assigned to each snippet. Among the four categories, the compound score measures the sum of all the lexicon ratings (positive, negative, and neutral) that have been normalized between -100% (most extreme negative) and +100% (most extreme positive). It is also called 'Normalized, weighted composite score'. The higher the

compound score, the more overall positive we obtain. It provides us with another angle to view the overall sentiment analysis.

Text Complexity Analysis

Text complexity analysis gives a statistical summary of the text data we collected. The text complexity analysis summarizes the number of online reviews for one product, number of characters, number of words, number of sentences, and number of unique words in those reviews. The text complexity analysis enables us to take one more dimension to view those text data, judge the text feature, and predict the product market confidently.

Review Data Summary

Table 1: Statistics of BHB product review data.

Data Resource	Amazon
Typical data	Product review
Data Type	Text
Product Type	Powder, Liquid, Capsule
# of Brands	26
# of Products	71
# of Reviews	30877
# of Sentences	105703
# of Words	1574171

Table 1 shows the statistics of Hydroxybutyrate (BHB) products' review data collected on Amazon.com. The BHB product reviews in text were collected within 2 months of the year 2019. The entire text dataset include 30877 reviews, 105703 sentences, and 1574171 words. Those product reviews reflect the clients' comments on 71 products under 26 brands.

Results

Word-level Sentiment Analysis

Table 2: Word-level sentiment analysis of lemon-series BHB powders and capsules.

#*	Powder, Capsule	Package, oz	Positive, %	Negative, %	Positive/Negative
1	Lemon	20	4.95	2.03	2.44
2	Lemon	25	4.22	2.51	1.68
3	Lemon Lime	20	5.33	1.75	3.05
4	Lemon Strawberry	25	5.64	1.63	3.46
5	Lemon Raspberry	20	5.63	1.97	2.86
6	Lime	30	5.92	2.44	2.43
7	Unflavored	16	3.61	2.18	1.66
8	Capsule	4	3.89	2.66	1.46
9	Capsule	4	3.57	3.37	1.06
10	Capsule	4	4.86	2.86	1.7
11	Capsule	4	6.05	2.38	2.54

Note: *#1 to #6 are flavored BHB products.

Word-level sentiment analysis utilizes lexicon to classify the words in the online reviews of one product into positive and negative categories. The process put all the recognized positive words and recognized negative words into two separate classes. Since the human language is abundant with the complicated expressions, the

portions of positive and negative words are relatively small. We then viewed those numbers comparatively. Table 2 partially showcases the word-level sentiment analysis of β -Hydroxybutyrate (BHB) powder and capsule products. The flavors used in BHB powder products include lemon, lime, lemon lime, lemon strawberry, and

lemon raspberry. Most of the flavored items were assigned with positive/negative ratios higher than the unflavored items. Only one lemon item had the positive/negative ratio 1.68. Three out of four capsule items received less than 2 or even lower positive/negative ratios. Such results suggest that appropriate flavoring improves the consumer acceptance of BHB products. Besides, word clouds were generated based on the online reviews of flavored/unflavored BHB products listed in Table 2.

feedback on the flavoring part of the product. We then summarized the top-3 high-frequency words in the word clouds of analyzed BHB products in Table 3. High-frequency words such as “keto”, “taste”, “product”, “flavor”, and “great” can be found in the word clouds of products #2, #3, #4, and #7 (See Table 3). The patterns of top-3 high-frequency words were not identical from product to product, however, the same words such as “taste” occurred repeatedly in different orders of BHB products’ high-frequency word lists. From those highly-repeated words, we speculate that the product development team behind those products attempted to grab their consumers by making tasty functional drink mix. In the word cloud of product #7, we found the word “diarrhea” clearly on the corner indicating the occurrence of such side effect in body. Similar side effects caused by magnesium citrate over intake were found in clinics, and it worsened gastrointestinal load. It also illustrates that not everyone adapts to the BHB supplements, and appropriate daily intake (e.g., amount, dosage, and intake approach) should be recommended.

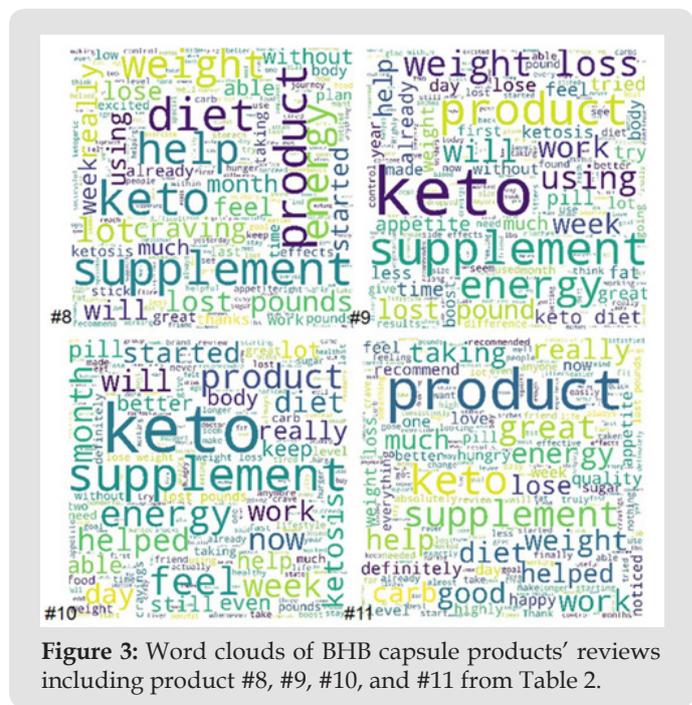
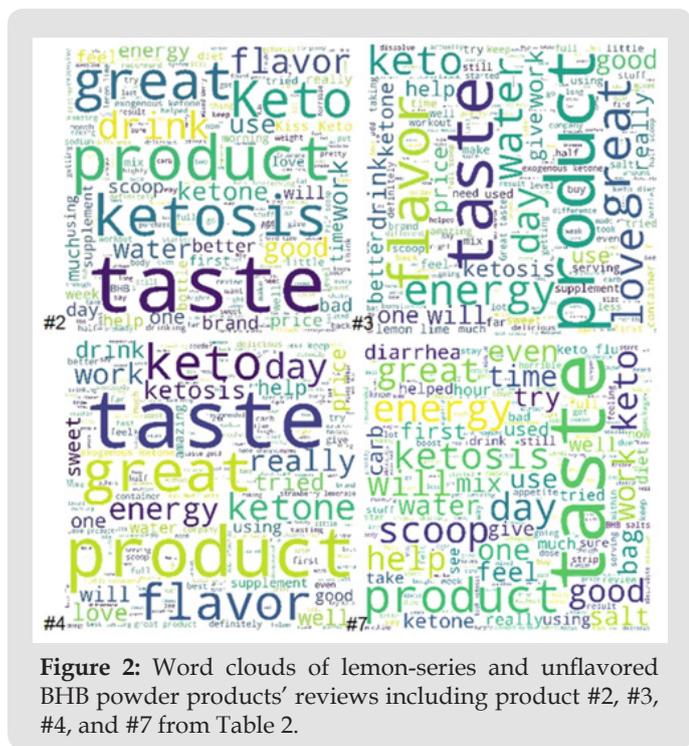


Figure 2 displays the word clouds of lemon-series and unflavored BHB powder products #2, #3, #4, and #7 from Table 2. The word size in the word cloud is proportional to the frequency of that word occurring in the reviews. For instance, the word cloud of product #2 clearly shows that consumers care about the taste and ketosis functions of the BHB product (i.e., increasing body ketone). The big words such as “flavor” and “great” suggested that the consumers who used product #2 expressed highly-positive

Table 3: High-frequency words in the word clouds of BHB product reviews.

#	Flavor	Package,	Word	#	Word	#	Word	#
		oz						
2	Lemon	25	keto	1606	taste	962	product	900
3	Lemon Lime	20	taste	105	product	94	flavor	66
4	Lemon Strawberry	25	keto	166	taste	118	great	69
7	Unflavored	16	taste	56	product	43	help	33
8	Capsule	4	keto	26	help	22	supplement	18
9	Capsule	4	keto	40	supplement	24	weight	23
10	Capsule	4	keto	38	supplement	24	help	17
11	Capsule	4	product	47	keto	25	help	20

We then extracted the online reviews of the rest BHB capsule products (i.e., product #8, #9, #10, and #11) in Table 2, and generated their word clouds (See Figure 3). We saw different big or small words on each word cloud in Figure 3. “lost pounds”, “weight loss”, “lose”, “weight” can be observed in the word clouds of product #8, #9, and #11, respectively, which reflects the weight loss function of BHB as supplement. The word “appetite” in the word cloud of product #9 might be related to the appetite disturbance caused by BHB. Then, we captured the word “energy” in the word clouds of product #9, #10, and #11 suggesting the energy enhancer function of BHB. Plus, the words “help”, “great”, “will”, “work”, “helped”, and “happy” in the word clouds in Figure 3 give us confidence in the BHB’s supplement functions. Their corresponding high-frequency words pattern is straightforward. The words “keto”, “help”, “supplement”, “product” in the word clouds of product #8 to #11 appeared in different frequency orders (See Table 3). We can see that the massive consumers put emphasis upon BHB’s functions. Many of them reflect positive feedbacks on BHB’s functions, especially weight loss and energy enhancer.

Sentence-level sentiment analysis: Flavor and Price

Figure 4 shows the sentence-level sentiment analysis of BHB products’ online reviews with flavor focus, including bubble chart of BHB products (Figure 4A), compound scores of selected branded BHB products (Figure 4B), and average compound scores of flavored BHB products (Figure 4C). In Figure 4A, some of the BHB products have large circles while others have small ones. Large circles indicate that the product review polarities are higher and more customers gave positive feedbacks than those who gave negative feedbacks. Other small circles suggest the adverse direction.

Flavored Products: From Figure 4A, we can see that all sorts of flavors such as apple, berry, lemon, orange, and etc. have been used to diversify the β -Hydroxybutyrate (BHB) products’ taste profiles. Those different flavored BHB products are priced within a wide range, from \$18 to \$99. Creative flavor combinations such as lemon-lime, lemon-raspberry, and orange-mango were observed in Figure 4A. Those BHB products with combined flavors actually had higher compound scores than other flavored BHB products. For instance, some apple or caramel flavored BHB products had high compound scores, however, more BHB products with combined flavors had such high compound scores, and some among them had the highest compound scores. Those BHB products with combined flavor actually occupied a certain space in Figure 4A. We selected some of the representative BHB products and placed them together in Figure 4B. The compound scores of those flavored BHB powder products were high, more than 20%. Besides, we grouped all the flavored BHB products together in Figure 4C. From Figure 4C, we found that most of the flavor categories have average compound scores higher than 20%. Five flavor categories among them have

average compound scores even higher than 25%, and three of them got average compound scores close to or higher than 30%. Those top products were flavored with apple, berry, cherry, lemon-lime, and lemon-strawberry flavors, most of which fell in the category of the citrus flavors. It is not too surprising. Citrus flavors have been investigated for a long time [19]. This flavor category has been widely-accepted to people all over the world, more importantly, is available and tastes similar globally. Those flavors have clean, refreshing tasting note, and are well-compatible with many other flavors and ingredients. Thus, it is relatively easy to commercialize citrus flavor-involved products around the world. The feasibility of design, process, and production also makes the application of citrus flavors convenient [20,21]. Citrus flavors have succeeded in bringing crisp sensation to various beverages, snacks and confections. Products with citrus flavors under brands such as Tropicana, Gatorade, Hi Chew can be found everywhere. The high average compound scores of those BHB products flavored with citrus flavors aligned with the historical popularity of citrus flavors. It is worth mentioning that the combination of different citrus flavors such as orange-mango, lemon-raspberry, and so forth can lead to even higher polarity of their product feedbacks. Such creation makes the monotonous supplements stand out and differentiate the brand among competitors.

Unflavored Products: For unflavored BHB products, most prices overlapped with each other within a narrow range from \$15 to \$40 (See Figure 4A). The compound scores of unflavored BHB products had a broad range from -22% to 37% (See Figures 4A, 4B). The compound scores of BHB capsule products fluctuated heavily. Among them, quite a few BHB capsule products had the compound scores above 20%, while others had the compound scores below 5%. The other few unflavored BHB powders and liquid had the compound scores of 12.21% (powder), 15.06% (powder), and 13.94% (liquid). Those items were good products, but they were not as competitive as those with higher compound scores. Although the unflavored BHB products were sold at low prices, they were still less popular or competitive than others. For instance, flavored BHB products under the brand C and E clearly exhibited the compound scores higher than the other unflavored BHB products (See Figure 4B). More additives such as flavors and sweeteners increase the product price, however the high quality of the resultant products still drive consumers back to the products. Besides, those products’ compound scores were calculated based on the certain amounts of consumers’ reviews. The compound scores of the BHB products such as A Capsule 2 and B Powder Unflavored 1 from Figure 4B were generated based on 39 and 170 reviews, respectively. The less appealing compound scores of those unflavored powder/capsule products are based on the common agreement among consumers. The monotonous products cannot arouse consumers’ continuous shopping desire.

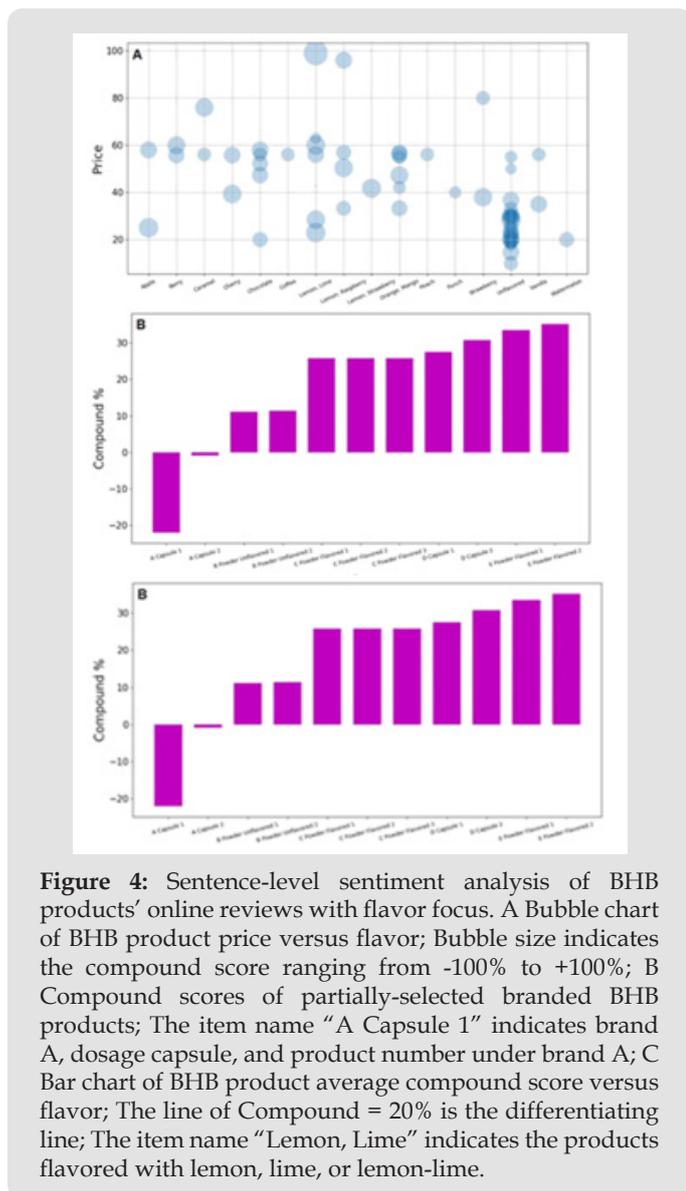


Figure 4: Sentence-level sentiment analysis of BHB products' online reviews with flavor focus. A Bubble chart of BHB product price versus flavor; Bubble size indicates the compound score ranging from -100% to +100%; B Compound scores of partially-selected branded BHB products; The item name "A Capsule 1" indicates brand A, dosage capsule, and product number under brand A; C Bar chart of BHB product average compound score versus flavor; The line of Compound = 20% is the differentiating line; The item name "Lemon, Lime" indicates the products flavored with lemon, lime, or lemon-lime.

Sentence-level sentiment analysis: Dosage and Package

The current BHB market provides our consumers with different packages. The packages of 1 oz to 55 oz were used to bottle BHB products with different dosage forms. Figure 5 shows the sentence-level sentiment analysis of BHB products' online reviews with package focus.

All Dosage: Figure 5A shows the bubble chart of BHB products plotted with package versus dosage format. From Figure 5A, we observed 3 major dosage forms on the current market of BHB products, including powder, capsule, and liquid. For BHB capsule, their packaging sizes were either 4 oz or 5 oz bottle, close to 120 cc or 150 cc. That size fit most of the bottling capacity of capsule manufactures. The BHB capsule products received a wide range of compound scores, from -22% to 37%. The BHB capsule products have straightforward packaging and functions, hence, it is less obvious to explain the fluctuation of their compound scores. Nevertheless, when we zoomed into each review of BHB capsules

with low compound scores, we found the reviews such as "Gives you a lot of energy but no weight loss", "It did nothing and there was no information with it to tell me what I should do to make it work, sorry I was very disappointed.", and "Did nothing at all. No change, not even a pound dropped combined with diet and exercise. Save your money." among all the other positive reviews. The body metabolisms of BHB products still deserve further investigation. More clinic studies of BHB products are needed to address this issue. The consumers might also be subjective and with incorrect expectation to some extent. On the other hand, the supplement manufacturers should review those insufficient customers' feedbacks and educate their clients with the appropriate use of their products. Unlike capsules, BHB powder products were commercialized with various packages shown in Figure 5A. There is no unified package size for the powder products. More creation becomes possible in bottling BHB powder products.

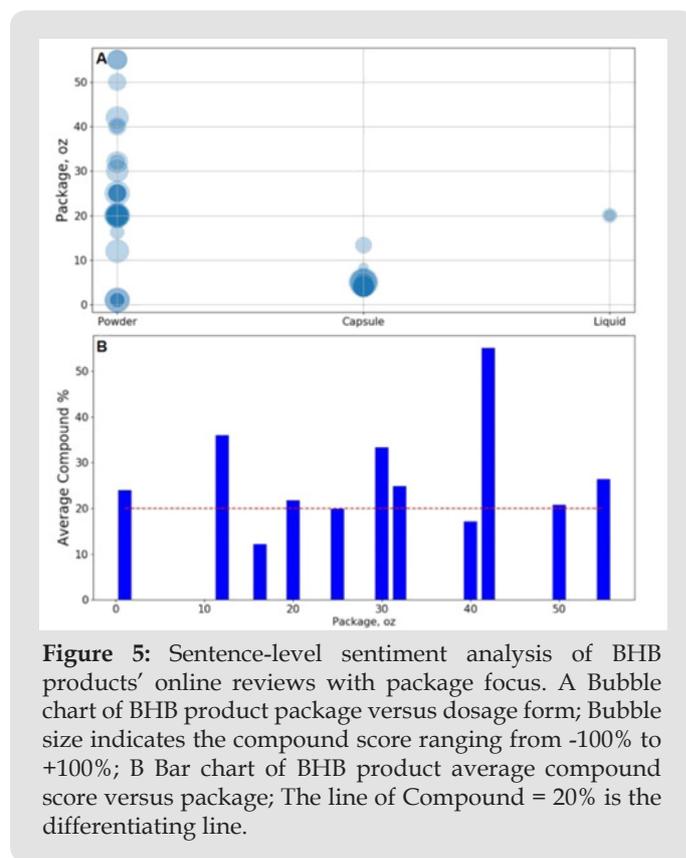


Figure 5: Sentence-level sentiment analysis of BHB products' online reviews with package focus. A Bubble chart of BHB product package versus dosage form; Bubble size indicates the compound score ranging from -100% to +100%; B Bar chart of BHB product average compound score versus package; The line of Compound = 20% is the differentiating line.

Powder Dosage: Figure 5B displays the average compound scores of BHB powder products in each package category. Most of the packages received the average compound scores higher than 20%. Among them, three packages such as 12 oz, 30 oz, and 42 oz bottles received the average compound scores higher than 30%. The average compound score of BHB powder products in 1 oz packet was also above 20%, suggesting that consumers should welcome the single-size samples prior to massive consumption. Some of those high polarity items such as BHB powder in 42 oz package did not have sufficient amount of online reviews. Unlike flavor factor, we did not observe exclusive impact of package upon

consumption orientation, especially for BHB powder products. All package items have experienced both high and low compound scores. Package size is not a dominant factor in BHB product design. Other factors including formula, price, and label all play a role in the market performance of the BHB products.

Complex Analysis

The sentiment analysis provides us with the polarity information of the text data, while the complex analysis summarizes the word number, sentence number, and character number in the reviews of each BHB product. The combination of both analyses enables us to understand the robustness of the consumers' feedbacks on BHB products. Table 4 lists the complex analysis of three brands' BHB products. It is part of the 71 BHB products' complex analyses.

The three products under brand A received more than 300 reviews referring to over 1000 sentences, 14000 words, and 65000 characters. The consumers paid certain amount of attention to the BHB products under brand A. Interestingly, the products under brand A had very similar patterns of text complexity, which was also found in the products of brand C. Five out of six products under brand C had almost overlapping numeric values in # of reviews, # of sentences, # of words, and # of characters with small deviations. Similar text complexity is observed under one brand, while large differences appear among brands. We can see that brands help differentiating products among companies. Rational consumers are willing to trust products with higher reputation more than others. Those products with high reputation automatically form a marketing event for their brands.

Table 4: Complex analysis display of three brands' BHB products.

Brand*	# of Reviews	# of Sentences	# of Words	# of Characters
A	458	1342	19177	88456
A	302	1005	14491	67271
A	458	1340	19177	88456
B	170	870	14538	68102
B	5	40	667	3216
B	29	109	1925	9349
B	18	49	932	4400
C	3490	12942	193635	889649
C	3490	12938	193636	889649
C	3490	12948	193637	889649
C	3490	12935	193636	889649
C	3490	12940	193635	889649
C	26	62	1035	4804

Note: *#1 to #6 are flavored BHB products.

To have a comprehensive understanding, we mapped the BHB products' distributions under the confinement of sentiment and complexity analyses. As such, Figure 6 presents the mapping of BHB products labeled with flavors under the combined conditions of online reviews' polarity and their complexity. In Figure. 6A and Figure 6B, the marks' colors indicate different flavors, while the same or similar color suggests the same flavor or similar ones. Figure 6A shows the flavor impact on product reviews' polarity in the context of the # of reviews. Data points scattered all over the plot in Figure 6A. For instance, we observed an unflavored BHB product with compound score -22% generated from 1 review, a lemon-lime BHB powder with compound score 55% from 3 reviews, and another lemon -lime BHB powder with compound score 23% from over 235 reviews. Products had very distinctive analytical results. For convenience, we divided the entire plot into 4 sections by using the boundary of compound% = 20 and # of Reviews or # of Sentences = 100. In Figure 6A, most of the unflavored BHB products were located in the center of the plot, while a certain amount of the unflavored BHB products sat in the left-down part of the figure, the

low compound score and low # of Reviews region. On the contrary, quite a few flavored BHB products gathered in the right-top part, the high compound score and high # of Reviews region. Besides, almost all the flavored BHB products had the compound scores higher than 20%, nevertheless, there were more unflavored BHB products with compound scores < 20% than those with compound scores > 20%. Such observations fortified our previous observation that flavored BHB products were more easily accepted by the massive consumers.

It should be noticed that the compound score is assigned based on the entire pool of reviews for one product. We should then take the text statistics of those reviews into consideration. Unlike the lengthy text in books, most of the online reviews for one product involve less than 5 sentences, and only a few of them directly express sentiment. We utilized # of Sentences as substitute of # of Reviews for the same analysis. It gives us another angle to view the product polarity in the context of the alternative text statistics. Figure 6B shows the plot of compound score versus # of Sentences with flavor label. Compared with Figure 6A, Figure 6B with # of

including flavors and packages were taken into consideration during analysis. In terms of flavors, they are not only edible ingredients but also multisensory phenomena with the integration of taste, olfactory, and other sensory information into a perceived property of the product rather than a collection of individual sensory attributes. For clients, the sensory pleasure is their motivation to consume a product and experience the flavoring journey again and again [22]. The sensory qualities from flavors reduce the product risk and increase its consumer affinity. When we consume supplements, especially sensory products, flavors become more important than the sum of other parts. In fact, flavor can be regarded as a primary factor in driving consumption behavior [23]. It was demonstrated that liking with flavored products increases chewing and swallowing rates [24]. In the current research, we observed that flavored BHB products were more popular than unflavored BHB products. The popularity of flavored BHB products is independent on the package volume. Among the flavored BHB products, the products with the combined citrus flavors such as lemon-raspberry can further increase the polarity of their online reviews. In other words, those particular flavored BHB products stand out among competitors.

Package is another factor when we conducted sentiment analysis of BHB products. It is the first visualization of product to the consumers. It asserts a critical role in product marketing and sales. Research shows that even the position of an image on the packaging affects consumers' perception of the product weight and package evaluation [25]. A considerable amount of investigations on multisensory product perception suggest that packaging features can bias consumers' flavor evaluations [26]. Another consumer research shows that altering packaging materials affect not only sustainability perceptions but also several other aspects including perceived taste and quality [27]. Our observation indicates that the packages of the flavored BHB products are distinct from those of the unflavored BHB products, especially packaging size. For the most of unflavored BHB products, their packaging sizes are limited in design. Compared with those unflavored BHB products, flavored BHB products have a wider range of package volumes which offers more possibilities for product marketing and education. In addition to the major labels of flavor and package, the sentiment analysis enables us to notice the fact that massive consumers emphasize on the BHB's functions such as weight loss and energy enhancer. Consumers are not willing to seeing that products lose those functions and work only as placebos. Some side effects of BHB products such as diarrhea suggest that we should continue more clinical studies and user education. From the complex analysis, brand implicitly deploys product differentiation and credit enhancement on this emerging market. The product differentiation refers to the business strategy of highlighting the unique features and benefits to separate it from competitors. When it functions, brand can create additional intangible value, consumer loyalty, and even market trend.

Conclusion

Sentiment analysis of β -Hydroxybutyrate (BHB) products' online consumer reviews was carried out to explore consumer insights on the emerging marketing of dietary supplements. Our observations demonstrate that flavoring plays a key role in the BHB product market together with other factors such as packaging and brand. Flavored BHB products are more popular than unflavored BHB products, and they are more acceptable by massive consumers despite of their high prices. Creative flavors such as lemon-raspberry enable BHB products to stand out among competitors. High volume packaging provides consumers with more possibilities of marketing and education. Meanwhile, we cannot ignore other factors such as active functions and brand building.

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