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Comparative Analysis of Nutritional Supplement Dosage Forms

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Abstract: ***This study provides a comparative analysis of four primary delivery methods for nutraceuticals: capsules, tablets, powders, and gummies. Each method offers distinct advantages and challenges in terms of bioavailability, palatability, production complexity, unit dosage, consumer acceptance, stability, cost, regulatory considerations, and environmental impact. Capsules and tablets generally provide pre-measured doses and controlled release mechanisms, while powders offer flexibility but require accurate measurement. Gummies excel in palatability but face challenges in dosage standardization. Despite the growing nutraceutical market, inconsistencies in dosage, regulation, and consumer understanding persist. To optimize the delivery of nutraceuticals and ensure consumer safety, further research, standardized guidelines, and comprehensive labeling are essential.***

Keywords: nutraceuticals, capsule, tablet, gummy, powder, dosage

1. Introduction

Whether it's medication or supplements, adhering to the correct dosage is critical in ensuring that they actually offer health benefits instead of becoming liabilities. The dosage might be calculated on several internal and external factors, like the potency of the chemical compounds, regular human tolerance (as per the studies), side effects, body weight, other medication, existing health conditions, etc. Another factor that may influence the dosage is how it's delivered. Different mediums like capsules, powder, and gummies and how they are consumed (mixed with something or standalone) might also influence the dosage to an extent.

It's also important to understand that supplements and similar ingestibles with positive health benefits might have more leeway when it comes to dosage compared to medication with active ingredients, which may prove more harmful in higher doses (and may not function in lower). Nutraceuticals fall under this category, and their dosages also vary in different mediums.

2. Understanding Nutraceuticals

The term nutraceuticals comes from the combination of natural and pharmaceuticals. It doesn't have a standard definition and a few heavily overlapping interpretations. Some of them focus on their dual role as food and medicine (Nasri, Baradaran, Shirzad, & Rafieian-Kopaei, 2014), while others focus on their supplemental nature. One well-regarded definition (Zeisel, 1999) is "A diet supplements that deliver a concentrated form of a presumed bioactive agent from a food, presented in a non-food matrix, and used to enhance health in dosages that exceed those that could be obtained from normal foods." Bioactive substances are the components within nutraceuticals that are responsible for their health-promoting properties. These are naturally occurring compounds found in foods that have beneficial effects on human health when consumed in adequate amounts.

Nutraceuticals, as the name and definition might imply, are derived mostly from natural sources. More accurately, natural food sources since they are supposed to be elements of food items with specific health benefits. However, it's not an explicit rule, and in some cases, elements of nutraceuticals may be derived from a variety of inorganic sources or even synthetically produced, although synthetic nutraceuticals are not well-received by the medical community for their adverse effects (S & Vadivel, 2016).

Some defining characteristics of nutraceuticals are:

- Nutraceuticals offer health benefits beyond what the human body absorbs from food naturally. One reason is the inadequate quantities of relevant components in the food supply, though how these components are processed alongside the food items as a whole is also a considerable factor. Nutraceuticals aim to enhance the impact of these elements by delivering them in the right form and quantity.
- The right quantity of relevant, useful components from food sources is achieved through concentrations. A nutraceutical might contain more of such a compound in a single pill or capsule than four or five units/helpings. An example would be "Raspberry Ketones". A typical capsule offers 500 mg of it, whereas an entire kilogram of raspberries contains one to four mg. So, a capsule may offer more ketones than 100 kg of raspberries. Hence, they offer a much higher dose of a desirable component of a natural food item than a human might ingest by eating the food itself in a reasonable amount of time.
- Nutraceuticals incorporate two useful elements of pharmaceutical products as well. They are extracted/isolated from a variety of sources and packaged in "non-food" forms. This includes capsules, tablets, powders, liquids, and even gummies.

Nutraceuticals occupy a unique position at the intersection of food and medicine. Their potential to prevent or manage specific health conditions has generated significant interest, yet their hybrid nature often leads to regulatory complexities. Derived from a wide array of sources, including plants, animals, and microorganisms, nutraceuticals come in diverse forms and compositions. This versatility allows for targeted

approaches to address various health concerns, such as immune support, digestive health, and joint health.

It's important to understand that despite over two decades of formal research and knowledge about the usefulness and healthy characteristics of certain food items dating back centuries, nutriceuticals are not a readily accepted class of drugs/ingestibles, and there are a healthy number of skeptics of nutriceuticals both in academia and in the broader healthcare community.

3. Types of Nutraceuticals

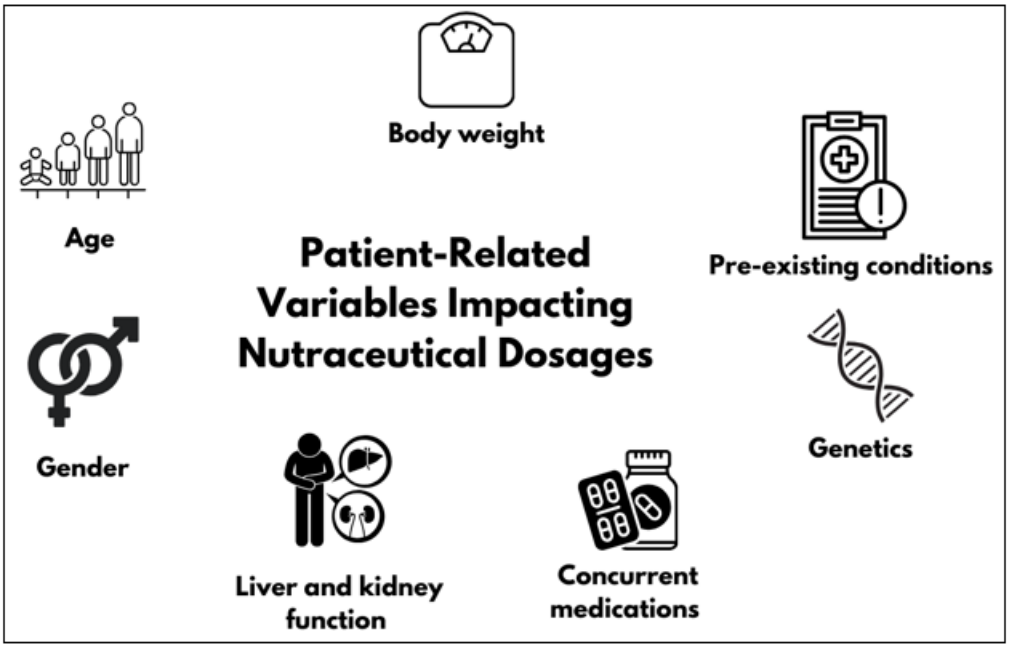
There is no formal or universally recognized classification or categorization for nutraceuticals. However, many academics and commercial producers of nutraceuticals have tried to classify them in their own ways. One set of researchers described seven types of nutraceuticals (Maurya, Chauhan, Yadav, Gangwar, & Maurya, 2021):

- **Functional foods:** Foods processed to increase nutritional value without altering taste or texture.
- **Dietary supplements:** Concentrated forms of nutrients in various forms for human consumption.
- **Medical foods:** Specially designed foods for individuals with specific health conditions.
- **Dietary fibers:** Nondigestible parts of food that promote gut health.
- **Farmaceuticals:** Genetically modified foods with enhanced health benefits.
- **Probiotics:** Beneficial microorganisms that promote gut health.
- **Prebiotics:** Nondigestible food components that support probiotic growth.

Another research defined 11 different types/classes of nutraceuticals with multiple subtypes (Rajam, Murugesan, Vadivelkumar, & Menachisundaram, 2019). It has additional nutraceutical classes like polyunsaturated fatty acids, antioxidant vitamins, polyphenols, etc. They even added "spices" as its own nutraceutical category.

This is relevant to the topic of dosage when it comes to nutraceuticals because it indicates the lack of standardization and the prevalent diversity of perspectives regarding nutraceuticals. This might also be reflected in the dosage in different mediums.

Different Delivery Methods and Factors Affecting Dosage



Like pharmaceuticals, nutraceuticals are also packaged (to be delivered) in a number of different ways for ingestion. We can also call them different "mediums." The efficacy of nutraceuticals is significantly impacted by their delivery method. How a nutraceutical is formulated and administered directly affects its absorption, distribution, metabolism, and excretion within the body, collectively known as pharmacokinetics. Consequently, understanding these delivery methods and the factors influencing dosage is crucial for optimizing the benefits of these supplements. For this paper, we are interested in four delivery methods:

- Capsules
- Tablets
- Gummies
- Powder

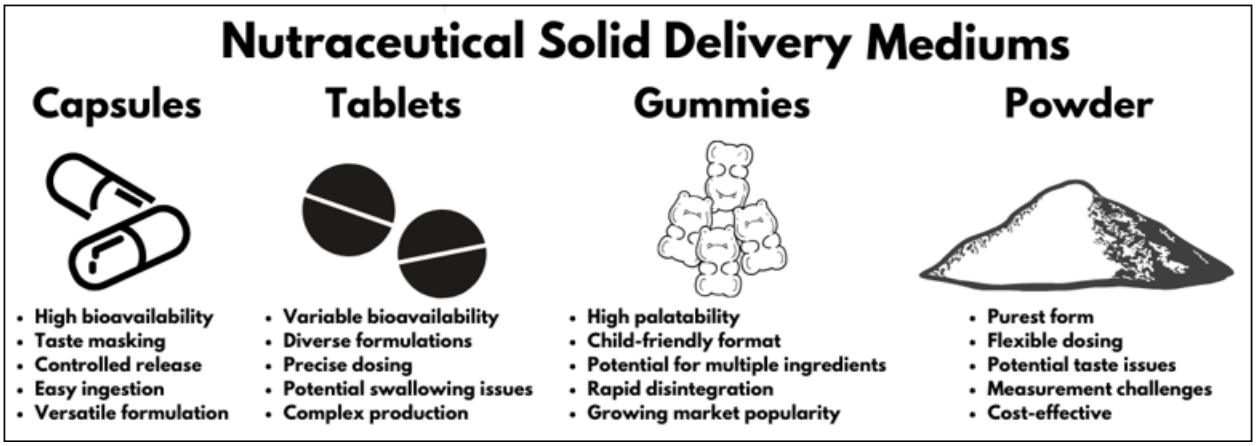
However, just as the dosage practices and optimal dosage for each of these delivery methods/mediums are crucial, understanding the factors that influence dosage is also important to consider. The core factors are:

1) **Body weight:** This is a fundamental consideration for almost all pharmaceuticals and nutraceuticals, as it influences the distribution and concentration of substances within the body.
2) **Pre-existing conditions:** Certain health conditions can affect how the body processes and responds to medications, supplements, and nutraceuticals. The goal should be to avoid any potential negative interaction. However, if no viable alternatives are available, negative interactions may be mitigated (while still achieving some positive results) by controlling the dosage.

3) **Age:** Metabolic rates, organ function, and overall physiology vary significantly with age, so doses are adjusted to ensure optimal results with minimal or no negative reactions.
4) **Gender:** Hormonal differences and body composition can influence drug and supplement response. However, the differences might not be as pronounced as they are for pharmaceuticals.
5) **Genetics:** Individual genetic variations can impact how the body metabolizes substances, and just like pre-existing medical conditions, certain genetic conditions and quirks can influence dosage. In some cases, genetics may allow a body to handle a higher dosage, while in others, it may warrant a lower dose of a nutraceutical product than people of comparable physiology. However, it's important to understand that pharmacogenomics research on nutraceuticals is quite limited.
6) **Liver and kidney function:** These organs are crucial for drug (pharmaceutical and nutraceutical) and metabolite elimination, affecting dosage requirements. They may influence the dosage even more than pre-existing conditions pertaining to other organs, like the heart and lungs.
7) **Concurrent medications:** Interactions between different drugs or supplements can influence dosage needs. These interactions may exist between pharmaceuticals and nutraceuticals, two nutraceuticals, and between supplements and nutraceuticals. This is why it's ideal to consult a physician before taking any nutraceuticals, even if they themselves don't offer any side effects.

Apart from these patient-related factors that influence dosage, a few external factors that may influence how nutraceuticals are packaged and what their recommended doses are in different mediums are:

- **Bioavailability:** Bioavailability refers to the extent and rate at which a substance is absorbed into the bloodstream. For nutraceuticals, this is crucial as it determines how much of the active ingredient reaches its intended target in the body. Factors such as the delivery method (oral, sublingual, intravenous, topical), the substance's solubility, particle size, and the presence of food can significantly influence bioavailability. Oral administration is the most common but is subject to first-pass metabolism in the liver, reducing the amount of active ingredient reaching the bloodstream.
- **Dosage Forms and Release Profiles:** The physical form of a nutraceutical, including factors like coatings, fillers, and binding agents, influences how and when its active ingredients are released. Capsules, tablets, gummies, and powders each have unique release profiles. For instance, capsules and tablets might have coatings to control drug release (enteric, sustained-release), while gummies offer a faster release due to their chewable nature. Understanding these release profiles is essential for optimizing drug delivery and efficacy.
- **Patient Compliance:** Adherence to prescribed dosage regimens is crucial for achieving the desired therapeutic effects. The choice of delivery method significantly impacts patient compliance. Factors such as convenience, palatability, and dosing frequency influence how well patients follow treatment plans. Improving compliance can lead to better health outcomes.
- **Regulatory Considerations:** Regulatory agencies play a pivotal role in ensuring the safety and efficacy of nutraceuticals and medications. They establish guidelines for dosage, labeling, and advertising. By setting standards and monitoring product safety, regulatory bodies protect public health. Adherence to these regulations is crucial for maintaining consumer trust and ensuring the quality of products. The regulations for nutraceuticals are usually less stringent, and there is greater variability among optimal doses and other aspects of administration among different countries and geographies.
- **Dosage Optimization:** Determining the optimal dosage for a nutraceutical involves a complex interplay of factors, including clinical trials, pharmacokinetic studies, and patient feedback. Clinical trials provide data on the safety and efficacy of different dosages, while pharmacokinetic studies help understand how the body processes the substance. Ultimately, finding the right dosage for an individual often requires a personalized approach based on factors such as age, weight, and medical history.



Capsules Dosage

Capsules are one of the most widely used methods for orally delivering (and ingesting) therapeutic substances, pharmaceuticals, nutraceuticals, and supplements. They have certain advantages over more commonplace tablets.

- They are easier to produce, require less equipment, and may take less time than comparable tablet production.

- Capsules can hold the "payload," i.e., the nutraceutical (or pharmaceutical) substances in various forms. It can be powder, semi-solids, nonaqueous liquids, etc. Hence, they often provide a more flexible option for encapsulating various nutraceutical compounds in their original form, potentially preserving their properties better than other delivery methods.
- Capsules can offer a higher degree of control over where in the gastrointestinal tracts they need to be absorbed in. Different capsule shell compounds dissolve in different places in the gastrointestinal tracts. Gelatin - the most common capsule material dissolves in the stomach. Enteric coatings can keep a capsule safe from stomach acids, allowing it to dissolve and release the nutraceutical substances in the small intestine. HPMC (hypromellose) is a plant-based alternative to gelatin and can be configured to be released in either the stomach or the small intestine.

There are other benefits as well, such as easier intake for individuals, better protection of the bioactive agents within, and the ability of the capsule shell material to mask the unpleasant taste of the compounds within.

Given these benefits, capsules are widely used for nutraceuticals and are the preferred medium in certain clinical trials. One such example is curcumin, titled "The Golden Nutraceutical," in a paper for its efficacy in multiple chronic conditions. It was delivered via capsule in multiple clinical trials (Keservani, Kesharwani, Sharma, Gautam, & Verma, 2017) in doses of (500–1200 mg/day) and few patients developed adverse symptoms. Another paper referred to clinical trials of curcumin where it was administered in both powder and capsule form, and it was identified the capsule offered much better bioavailability and might offer the same therapeutic effects in smaller doses due to its efficiency compared to other mediums (Kunnumakkara et al., 2016).
Another major advantage of capsules is that they can effectively deliver probiotic nutraceuticals without drastically raising the manufacturing cost. Since they contain live organisms, they are more susceptible to environmental damage and tend to fare better in capsules than tablets, especially if the tablets are not coated/protected using special measures designed to keep the microorganisms safe. Capsules can also keep them alive until they reach the desired place in the gastrointestinal tract without being killed by stomach acids prematurely.

Consumability is another factor in play here (Gowrimeenal, Banumathi, Premalatha, Rajesh, & Arulmozhiselvan, 2018). Patients might avoid the nutraceutical in other forms, especially powder forms, if the taste is too bitter, making it inedible. However, an adequate amount of that nutraceutical compound may be delivered effectively in powder form.

Now, let's see how these three factors influence nutraceutical dosage in capsule form.

- Since capsules are easier to ingest and are likely to deliver the entire dose of the bioactive compound at the desired place within the gastrointestinal tract, there is no or minimal loss factor, so the dosage can be kept at an optimal level. Some nutraceutical compounds are indeed taken in higher doses in other forms. An example is garcinia cambogia, a substance used widely for weight loss. Its studies in powder form maintained a dose of 3,000 to 5,000 mg per day (Ishii et al., 2003). While there is no definitive dosage in capsule form, an overview of multiple trials suggested the dosage between 900 mg and 1,500 mg per day (Fassina et al., 2015). However, a few samples observed on Amazon of the most famous nutraceutical products based on this compound revealed a recommended daily dose of around 3,000, though it's still lower than powder.
- Its effective bioavailability also allows for the maintenance of optimal dosage since most of it is effectively absorbed and delivers the desired therapeutic results.
- They can keep the dosage for probiotic nutraceuticals at a minimum because they can safely be delivered to the desired spot in optimal numbers, compared to other forms where the dose may have to be expanded to ensure that the relevant amount of microorganisms is absorbed.

Capsules offer several advantages influencing nutraceutical dosage. Beyond ease of ingestion and controlled release, the specific formulation of the capsule plays a crucial role. The capsule shell material, such as gelatin, HPMC, or enteric coatings, determines where the contents are released in the gastrointestinal tract. Additionally, the form of the nutraceutical within the capsule (powder, pellet, liquid) impacts its dissolution rate and absorption. Factors like particle size, excipients, and the presence of other ingredients can further influence bioavailability.

Tablets Dosage

Just like capsules, tablets have their own strengths as a medicine delivery medium and are the most widely used (if not *the* widely used) form in which nutraceuticals are developed and released in the market. Tablets are considered a unit dose, just like capsules. Nutraceutical tablets can be compressed using the same methods used for pharmaceutical tablets (like punching machines), and they may contain ingredients other than the bioactive nutraceutical agent. The quantity of the active ingredient in the tablet may vary based on several factors, including tolerance in human subjects and the quantity of other ingredients. For example, one study was conducted on the formulation of clove and cinnamon-based nutraceutical tablets. In the 400 mg tablet, the nutraceutical "compound" (the active ingredient) was only 100 mg. Whereas lactose and mannitol, which were used as diluents in the table, were used in almost three times the quantity-290 mg (Nagaich, Pal, Bharti, & Gulati, 2014).
A tablet's bioavailability, or the rate and extent to which the active ingredient is absorbed into the bloodstream, is influenced by several factors. Key among these are:

- **Disintegration and dissolution:** A tablet must first disintegrate into smaller particles and then dissolve in the gastrointestinal fluids before the drug can be absorbed. Factors like tablet hardness, compression force, and the use of disintegrants can influence this process.
- **Particle size:** Smaller particle size generally enhances dissolution rate and, consequently, bioavailability. Particle size, in this context, refers to the size of the individual particles of the active nutraceutical ingredient (API) or other components within the tablet formulation.

- **Excipients:** The choice of excipients can significantly impact tablet disintegration, dissolution, and drug release. For instance, hydrophilic excipients can accelerate disintegration, while hydrophobic excipients may delay it.

Tablets come in various forms, each impacting dosage delivery. Chewable tablets, ideal for those with swallowing difficulties, offer rapid absorption but may have an uneven distribution. Coated tablets can mask the taste, protect the drug, or control release (like enteric coatings that delay stomach breakdown). Sustained-release tablets deliver the drug gradually, improving compliance but potentially affecting peak concentration and duration of action. These diverse formulations cater to specific needs while requiring careful design to optimize dosage and therapeutic outcomes.

A tablet's interaction with stomach acid and enzymes is crucial. Tablet composition and coatings influence how quickly it breaks down (disintegration) and releases the drug (dissolution). Immediate-release tablets need to dissolve fast, while enteric-coated ones resist stomach acid until reaching the intestines. The stomach's acidity affects how well the drug dissolves and absorbs. Tablets can be designed to release the drug gradually, similar to capsules, but achieving this requires careful formulation due to stomach conditions.

Nutraceutical tablets also pose unique formulation challenges compared to traditional pharmaceutical tablets. The often complex composition of nutraceutical ingredients, which can include a high concentration of active compounds, necessitates careful consideration of excipient selection and inclusion to achieve desired tablet properties. Additionally, the variability in raw material characteristics, such as particle size, flowability, and moisture content, can significantly impact the tablet manufacturing process. The need to deliver sufficient quantities of active ingredients while maintaining acceptable tablet attributes often results in formulations with a higher proportion of active components relative to excipients. These factors, combined with the potential abrasiveness and hardness of some nutraceutical materials, can accelerate equipment wear and impact overall production efficiency.

Furthermore, the design and production of visually appealing nutraceutical tablets can be challenging due to the frequent use of natural colorants and textured appearances. These aesthetic considerations, coupled with the technical complexities of tablet formulation, underscore the need for specialized knowledge and expertise in the development of nutraceutical products (Patel, 2020).

One important limitation of nutraceutical tablets is that it’s not widely used for probiotics. However, the right formulation approach can keep probiotic microorganisms alive for an adequately long shelf-life, though the cost may be higher than the comparable dosage of probiotic substances being delivered in capsule form (Nguyen, Anton, & Vandamme, 2016).

Gummies Dosage

Gummies haven't yet carved as big a slice of the nutraceutical markets as capsules and tablets, but they are gaining considerable traction. Their taste and aesthetic appeal make them more palatable for a wide range of users, including children. The substances that control the sweetness and consistency of the gummies may also influence the overall dosage of nutraceuticals in this format because, like capsule shells and tablet excipients, they are a critical part of “delivery” in this mode (Bartkiene et al., 2023).

Gummies might serve as a novel delivery method for certain nutraceutical bioactive components/substances that might otherwise be susceptible to deterioration from elements like sunlight. This makes them a more palatable alternative to capsules that might have otherwise been used to protect the bioactive components (Liu et al., 2024). They might also provide a suitable delivery system for nutraceuticals that require protection from other factors like heat or oxygen. This could potentially expand the range of bioactive compounds that can be effectively delivered to consumers in a palatable form.

As for the dosage of active ingredients in gummies, one factor to consider is that nutraceutical gummies more often offer a blend of active ingredients rather than delivering a single one. It comes with benefits like synergy between different active ingredients that might enhance or complement the positive health impact of one another. The variety of ingredients can cater to different nutritional needs and preferences, appealing to a wider range of consumers. Blending multiple ingredients can also help by masking undesirable tastes or textures, increasing its palatability.

Gummies, like tablets and capsules, are ingested orally and begin their journey through the gastrointestinal (GI) tract. Unlike tablets and capsules, which typically disintegrate in the stomach or small intestine, gummies undergo a different dissolution process. The gummy matrix itself starts to dissolve in the mouth, releasing some of the active ingredients directly into the oral mucosa. This initial release can lead to a quicker onset of action for certain compounds compared to tablets or capsules. As the gummy is swallowed, it continues to dissolve in the stomach and small intestine, where the majority of absorption takes place.

Bioavailability, i.e., the proportion of an administered drug that reaches the systemic circulation unchanged, is another important factor to consider in the context of the dosage of gummies. While specific studies comparing the bioavailability of gummies to tablets and capsules for identical compounds are limited, general trends can be observed. Gummies, due to their rapid disintegration in the oral cavity and subsequent exposure to digestive enzymes, may offer potential advantages in terms of bioavailability for certain compounds. However, factors such as the specific ingredients, formulation, and individual physiological differences can significantly influence the overall bioavailability of any dosage form.

Powder Dosage

Nutraceutical powders differ significantly from other dosage forms, such as capsules, tablets, and gummies. Unlike these pre-portioned options, powders are typically sold in bulk and require users to measure out specific amounts based on weight or volume. Powdered nutraceuticals often provide a more direct and unadulterated form of the active ingredients

compared to encapsulated or compressed formats. Unlike tablets, capsules, or gummies, which incorporate additional components for structure and delivery, powders typically contain a higher concentration of the desired nutrients. This purity can be beneficial for individuals seeking maximum potency or those with sensitivities to additives. Additionally, powders offer greater flexibility in terms of dosage, allowing consumers to precisely control the amount of each nutrient consumed. However, this lack of pre-measured dosing can also introduce variability in consumption and may pose challenges for the accurate intake of bioactive compounds. The purity might also introduce another challenge pertaining to its palatability since undesired texture and taste might be present in its most raw form. While excipients can be added to enhance flowability or mask taste, the range of possibilities is narrower.

But there is a benefit as well. Patients/individuals with certain pre-existing conditions may have trouble ingesting or processing tablets or capsules or even gummies. It might be because of the added ingredients in their bio-active vehicles. They may benefit from the availability of the relevant nutraceutical components in their raw/basic form with minimal additives (Frankling, et al., 2020).

The bioavailability of powdered nutraceuticals can vary significantly compared to other dosage forms.

While powders offer direct exposure of the active ingredients to the digestive system, several factors influence their absorption and overall bioavailability:

- **Particle size:** Smaller particle size generally leads to faster dissolution and better absorption.
- **Solubility:** The solubility of the active ingredients in the gastrointestinal fluids impacts bioavailability.
- **Interactions with food:** Consuming powders with food can affect the rate and extent of absorption.
- **Individual factors:** Factors such as gut health, overall health, and metabolism can influence how well the body absorbs nutrients from powders.

In comparison to capsules and tablets, powdered nutraceuticals might offer faster onset of action due to the absence of a dosage form barrier. However, the actual bioavailability can be influenced by various factors, and individual responses may vary. It's essential to consider these factors when evaluating the effectiveness of powdered nutraceuticals.

Powder production involves processes like drying, milling, and blending, which can impact product consistency and quality. Unlike capsules and tablets, which often require specialized equipment and controlled environments, powder production can be relatively simpler, though maintaining hygiene and preventing contamination remains crucial. In fact, powder might be considered the default form in which most nutraceutical compounds were classically extracted or isolated.

Powdered nutraceuticals may pose challenges in terms of consumer acceptance due to factors like messiness, difficulty in measuring accurate doses, and potentially unpleasant taste. Capsules and tablets offer convenience and precision in dosing, often with added features like taste masking. However, powders can be more adaptable to dietary restrictions or preferences, as they can be incorporated into various foods and beverages.

Dosage Comparison for Different Nutraceuticals Classes

Feature	Capsules	Tablets	Powders	Gummies
Bioavailability	Generally high, especially with controlled release	Can vary based on formulation, disintegration, and dissolution	Influenced by particle size, solubility, and interactions with food	Potential for rapid absorption due to oral disintegration, but overall bioavailability can vary
Palatability	Often high due to taste masking	It can vary depending on the formulation, but generally acceptable	Typically low due to taste and texture	High due to pleasant taste and texture
Production Complexity	Moderate, requiring encapsulation process	Complex due to compression and coating processes	Relatively simple but requires careful handling to maintain quality	Moderate complexity due to formulation and molding processes
Unit Dose	Pre-measured	Pre-measured	Typically sold in bulk	Pre-measured
Consumer Acceptance	Generally high due to convenience and ease of use	High, but can vary based on tablet size and swallowing difficulties	Can be lower due to messiness and difficulty in measuring accurate doses	High, especially among children and those seeking convenient options
Stability and Shelf Life	Generally good, especially with proper storage	Can vary depending on formulation and coating	Can be sensitive to moisture, light, and oxygen	Can be influenced by sugar content and storage conditions
Cost of Production	Moderate, influenced by shell material and filling process	Can vary based on formulation and equipment	Generally lower due to simpler production process	Can be higher due to additional ingredients and processing
Regulatory Considerations	Subject to regulations for dietary supplements, with specific requirements for capsule shells and contents	Subject to regulations for dietary supplements, with additional considerations for tablet coatings and compression	Generally less regulated than other forms, but still subject to food safety standards	Subject to regulations for dietary supplements, with specific requirements for ingredients and manufacturing processes
Environmental Impact	Can vary based on packaging materials and production processes	Similar to capsules, with additional considerations for tablet coatings	Generally lower environmental impact due to simpler packaging	Potential for higher environmental impact due to packaging and sugar content

4. Conclusion

The four delivery matrices/mediums represent the four solid forms of nutraceuticals available in the market. Despite two decades of research, clinical studies, and centuries of traditions backing up the medicinal properties of certain food items, nutraceuticals have yet to become as standardized as pharmaceuticals. This is why there is a clear lack of standardization of dosage in each of the four mediums. Factors such as the complex nature of botanical ingredients and variations in manufacturing processes also contribute to inconsistencies in dosage and efficacy. Once they are more formally researched and their long-term impacts better understood, different regulatory bodies might start drafting formal dosage requirements for different nutraceutical compounds.

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