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Effervescent Tablets: Comprehensive Review on Formulation Strategies, Manufacturing Technologies, and Quality Evaluation

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Abstract: Effervescent tablets are specialized oral dosage forms that have gained significant popularity in both pharmaceutical preparations and dietary supplement formulations due to their rapid disintegration and enhanced patient acceptability. These tablets contain a combination of acidic components such as citric or tartaric acid and alkaline components like sodium bicarbonate, which react in the presence of water to release carbon dioxide. The liberation of CO_2 improves the solubility and palatability of the formulation, resulting in a clear, flavoured solution that is easy to administer, particularly for geriatric, paediatric, and dysphagic patients who have difficulty swallowing conventional tablets. Despite the advantages, effervescent tablets require careful selection and balance of excipients including binders, fillers, sweeteners, polymers, and water-soluble lubricants to maintain stability and prevent premature effervescent reactions. They are highly sensitive to moisture; therefore, manufacturing must be carried out under controlled environmental conditions, typically below 25°C and low humidity, with moisture-protective packaging to ensure product integrity. Various manufacturing methods such as wet granulation, dry granulation, direct compression, and advanced granulation technologies are utilized to produce tablets with suitable mechanical strength and dissolution properties. Quality evaluation parameters including hardness, friability, effervescence time, pH, moisture content, and uniformity of content are essential for ensuring therapeutic performance. Although effervescent tablets provide rapid onset of action, improved taste, and patient compliance, challenges such as higher production cost and specialized equipment requirements remain. Continued advancements in formulation and process technologies are supporting the growing application and commercial importance of effervescent tablet systems.

Keywords: *Effervescent Tablets; Acid–Base Reaction; Bioavailability; Manufacturing Techniques; Patient Compliance.*

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I. INTRODUCTION

Effervescent tablets are used by many people for their benefits. In addition to pharmaceutical goods, they are employed as dietary supplements. Even though oral intake is the most popular non-invasive method of medicine administration, effervescent technology has benefits that go beyond just being user-friendly and easy for patients to adhere to. These tablets have a flavour and are well-liked by many [1]. Effervescent tablets offer a few benefits, including quick dissolving, the production of a tasty and stimulating drink, and possibly improved medication absorption. via the release of carbon dioxide[2]. Despite the numerous drawbacks of oral medications, such as inadequate absorption, they

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remain the most widely used method of drug administration, which causes a delay in the onset of action. Giving the medication in liquid form will help to address the issue, even though some of the active medicinal components have poor stability in liquid form[3]. According to the Indian Pharmacopoeia, effervescent tablets must be uncoated and contain acidic substances mixed with carbonates or bicarbonates that react quickly in water. sometimes with taste enhancers and carbon dioxide. Either dissolve these pills or mix them with water before taking them[4]. Most of the chemical processes in effervescent tablets are acid-base interactions. Carbon dioxide is released by this mechanism at the end. Tartaric, malic, citric, fumaric, and adipic acids are a few of the acids used. Despite the high cost of malic acid, citric acid, which is frequently sought after for its citrus flavour, enhances the overall flavour. Fumaric, malic, and tartaric acids may be taken in slightly lower amounts because of their limited solubility in water[5]. Carbon dioxide is produced as these components rapidly react with water. Not only does CO2 generation enhance the dissolvability of the active pharmaceutical component (API) in water but also it serves to hide the taste of the beverage[6]. As the reaction results in effervescent formulations, acid-base neutralization events produce CO2 and generate buffered salts. Citric acid and sodium bicarbonate are the most frequently used effervescent response. Water speeds up this process even in very small amounts. All goods sensitive to moisture or effervescent in character are kept in dry conditions to help to avoid reactions [7 - 9]. Water-soluble lubricants are used to stop insoluble sediment accumulating on the surface of the water. Saccharin is included to sweeten the recipe as sucrose absorbs moisture and increases tablet weight needlessly. The production is carried out under environmental circumstances to prevent effervescent reactions. The packaging's relative humidity stays under 25 percent at 25 degrees C. After the container is opened, the consistency of the product can also be influenced by moisture from user hands and the surrounding environment. The most often used effervescent pill is aspirin. Specialized delivery methods—vesicle-based carriers meant to carry medicines to desired locations, for example—have emerged from this[10]. These systems use liposome-based delivery and nano or micro scale nanoparticle-based drug administration[11].

Fig 1 Effervescent Tablet Disintegration in Liquid

- *Excipient Used in Effervescent Tablet [12 - 20]*

Table 1 Excipients in Effervescent Tablets

S.NO	EXCIPIENTS	ROLES
1	Tartaric acid	Effervescent agent
2	HPMC hydro alcoholic gel	Binder
3	Citric acid	Effervescent agent
4	Sodium bicarbonate	Effervescent agent
5	EudragitL10	Polymer
6	Lactose monohydrate	Filler and binder
7	PovidoneK30	Polymer and binder
8	Sodium carboxy methylcellulose	Binder
9	Magnesium powder	Effervescent reaction
10	Citrocoat®N	Effervescent reaction
11	Ascorbic acid	Antioxidant
12	Maltose	Filler and sweetener
13	Mannitol	Filler and sweetener
14	Lactose	Filler and sweetener
15	Dextrates	Filler and sweetener
16	Sodium stearyl fumarate	Lubricant
17	Adipic acid	Lubricant
18	Eudragit®RS100	Polymer
19	Carbopol934P	Polymer and binder
20	Talc	Lubricant, glidant and diluent
21	Magnesium stearate	Lubricant
22	Avecil102	Direct compression filler
23	Micro crystalline cellulose	Binder and diluent
24	HPMC 90SH 15.000	Retardant and swellable hydrophilic polymer
25	Karaya gum	Retardant and swellable hydrophilic polymer.
26	PolyethyleneoxideWSR303 (PEO)	Polymer

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27	Sodium bicarbonate	Effervescent agent
28	KyrosT-314	Super disintegrant
29	PVP	Synthetic polymer and binder
30	PEG6000	Polymer and solvent
31	Sucralose 8	Sweetener
32	Propyl alcohol	Solvent
33	Sodium benzoate or propylene glycol	Lubricant
34	Citrous oil	Flavouring agent

➢ *Active Ingredient*

- NSAIDs - Aspirin, Ibuprofen
- Mineral Supplements - Calcium, Magnesium
- Antibiotics - Amoxicillin, Erythromycin
- Amino Acids - Glutamine, Lysine
- Electrolytes - Sodium, Potassium
- Enzymes - Bromelain, Papain
- Herbal Extracts - Ginkgo biloba
- Antacids - Calcium carbonate, Magnesium hydroxide

➢ *Mechanism of Effervescent Tablet*

Chemical Reaction Involved in Effervescent Tablet

- $C_6H_8O_7.H_2O + 3NaHCO_3 (aq) \rightarrow Na_3C_6H_5O_7 + 4H_2O + 3CO_2 (g) \uparrow$
- Citric acid + Sodium bicarbonate → Sodium citrate + Water + Carbon dioxide
- $C_4H_6O_6 + 2\ NaHCO_3 \rightarrow Na_2C_4H_4O_6 + 2H_2O + 2CO_2 (g) \uparrow$
- Tartaric acid + Sodium bicarbonate → Sodium tartrate + Water + Carbon-dioxide

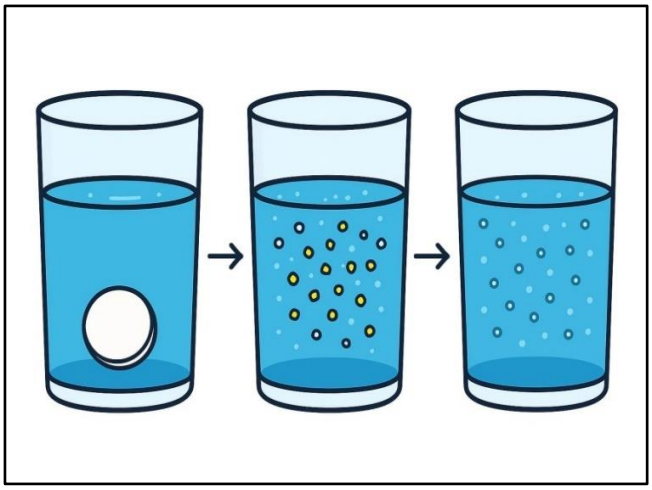

Fig 2 Mechanism of Effervescent Tablet Disintegration

This reaction occurs in the presence of water, even with small amounts of a catalysing agent, and because water is one of the reaction products, it accelerates the rate of reaction, leading to difficulty in stopping the reaction. Therefore, the manufacturing and storage of effervescent products is planned by minimizing contact with water[21].

Effervescent tablets also include various ingredients such as lubricants, binders, flavours, fillers, and sweeteners. To avoid the sticking of the tablet to the machine, water-soluble lubricants are used, which also prevent the formation of insoluble slurry on the water surface. As sucrose is hygroscopic (which absorbs water easily), it results in a rise in tablet mass; hence, other sweeteners like aspartame, mannitol, and sucralose are often used[22].

➢ *Advantages of Effervescent Tablet [23 - 25]*

- Improved taste
- faster absorption
- presentable, fizzy tablets
- Rapid on set action
- Enhanced bioavailability
- Better portability.
- Adapting the 3D printing technology advantages
- Improved patient's compliance
- Stability during storage

➢ *Limitation of Effervescent Tablet [26 - 27]*

- Larger tablets
- complex production process
- delicate packaging process
- Controlled environmental conditions during the manufacturing process
- Unpleasant taste of some ingredients
- Excipients are costly

II. MANUFACTURING TECHNIQUES

➢ *Effervescent Tablet Production*

Effervescent tablet Despite the use of specialized machinery and regulated environmental conditions, effervescent tablets are made in a manner resembling ordinary tablets. Maintaining a tight control over temperature and humidity prevents raw materials from absorbing moisture and causing effervescent responses. Low relative humidity—no more than 25%—and moderate to cool temperatures—25°C—are necessary to avoid product deterioration and adherence to equipment. Granulation is the most popular approach for making tablets with the desired properties. There are a few granulation methods, including one-step granulation using water or organic solvents and two-step granulation, in which the acid and alkali phases are granulated separately.

➢ *Wet Granutation*

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Fig 3 Wet Granulation Process

Wet granulation is the most advised method for effervescent granulation, even if it has some major drawbacks. The result of this procedure is homogeneous granules that may be compressed and uniform tablets, whether by weight or by active ingredient content [28].

➢ *Two-Step Granulation Procedure*

The acidic and basic components are first granulated separately and then dry-mixed using conventional equipment, such as a fluid bed spray granulator, single pot, or high-shear granulator, before adding lubricant for tableting. The other option is to granulate one of the effervescent sources and include the other as a powder during the last mixing process, along with other ingredients like flavors and lubricants. By skipping the complete granulation stage, this approach increases output and reduces expenditures.

➢ *A One-Step Approach to Granulation*

The one-step granulation method entails granulating acidic and alkaline elements together with a little amount of water or organic solvents, such as alcohol, isopropanol, or other solvents, along with a binder. By controlling effervescent reactions and causing granule formation, this method creates dry effervescent granules immediately. The organic solvent must not dissolve the effervescent or other ingredients.

➢ *Fluidized Bed Granulation*

With the aid of fluid-bed granulator-dryer technology, the components of an effervescent combination are pulverized in a single process. This method involves suspending a dry mixture of an acid source and a carbonate source in a heated air stream to produce a fluidized bed. When a small amount of the most prevalent granulating fluid, water,

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is introduced, it briefly interacts before evaporating. When the spraying of water ceases and the drying process is finished with warm, dry air [29] .the reaction is over. A Rotor fluid bed spray granulator may be used as an alternative method for producing effervescent granules. The interaction between the two effervescent system components is lessened by this procedure. Making effervescent granules requires this procedure, which involves two or three steps in a row. The initial step is the granulation of alkaline elements in the rotating fluid bed. The following step involves spraying the alkaline spheres with acidic powders and the granulating solution. This causes the spheres to develop an outside acidic coating that is separated from the binder by a neutral layer. The process of agglomeration is complete, and then the drying process begins.

➢ *Granulation with High Shear*

Using high-shear granulator-dryer technology, the granulation process can be quickly changed to the drying process by creating a vacuum within the bowl. As a result, the water's boiling point drops quickly, and the bowl warms up, providing the heat necessary for the evaporation [30] . The effervescent reaction ceased when the water on the surface of the moist granules vanished in a matter of seconds. Additionally, a vacuum can be used in conjunction with microwave radiation to dry effervescent granules and halt the effervescent process. Comparison of Granulation Technologies. Available from [31] . This kind of granulation can be performed utilizing granulation technologies, where a vacuum can be used to halt the reaction[32].

III. DRY GRANULATION

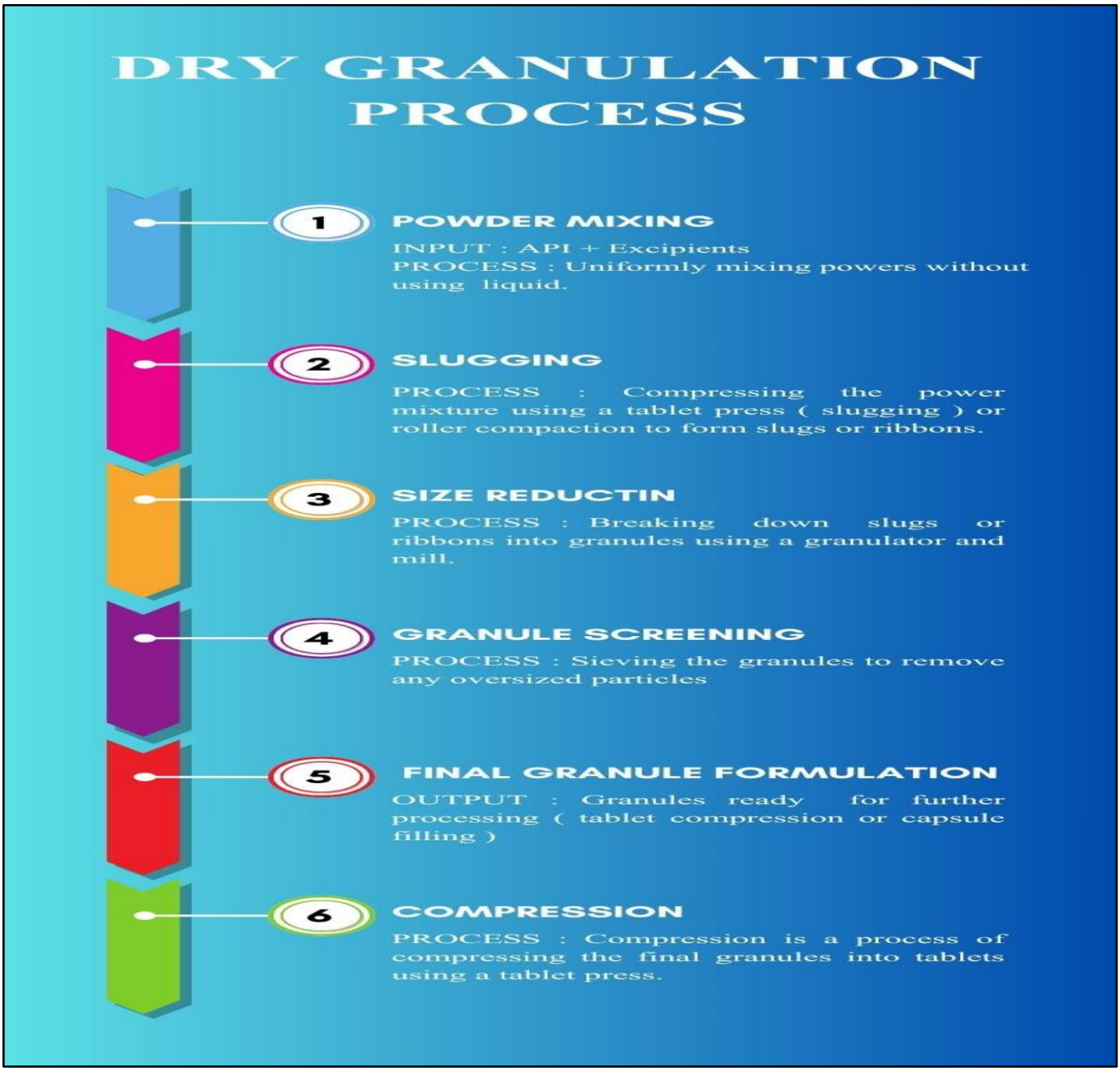

Fig 4 Dry Granulation Process

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The wet granulation method, which breaks down the material, initiates the effervescent reaction. Consequently, other options have been created. One of these methods is dry granulation by slugging, which involves using roller compactors to compress huge tablets or slugs, or directly compressed other forms. The wet granulation procedure has been replaced by these, which are the most effective alternatives.

➢ *Slugging*

A roller compactor or chilsonator is frequently used to compress mixed powders between two counter-rotating rollers under higher pressure to create slugs or big pills. Afterward, the resulting slugs are processed to the right size for tablet granulation. In order to produce slugs, lubrication may be necessary. With acidic and basic compounds, this approach works well for creating effervescent pills using dry granulation. Nonetheless, it is only appropriate for making little batches of tablets and requires the use of expensive excipients. The method is straightforward, economical, boosts product output, and reduces the need for personnel and space while simultaneously lowering the demand for air circulation.

➢ *Direct Compression*

Direct compression has been successfully utilized as an alternative method for dry granulation in the production of effervescent acetylsalicylic acid tablets. It is helpful to address problems with the operational effectiveness and stability of the process. The utilization of this technology in real-world applications is restricted, though, due to the necessity for complicated raw material combinations that are compressible, free-flowing, and non-segregating, which can only be achieved in the most ideal manufacturing conditions.

➢ *Heating-Induced Granulation*

Methods of dry granulation include hot melt granulation, which may be used in place of wet granulation. The particles of the powder mixer are agglomerated during hot melt granulation by the hydration water that is liberated when hydrated citric acid is melted to form the granulating liquid [33]. After that, the granules are cooled to get the necessary strength and mechanical stability. In a fluid bed spray-granulator, hot melt granulation can be carried out using low melting point polymers like PEGs as binders or using a high-shear granulator-dryer. Hot melt extrusion is another distinctive method that necessitates an extrusion die [34,35] . extruders with temperature-controllable heating zones, and a hot-melt extrudable binder.

➢ *Pre Formulation [36 - 47]*

- *Angle of Repose (θ)*

The angle of repose can be used to calculate the frictional force in a free powder or granules. The maximum possible angle between the surface of the powder pile and the horizontal plane is known as the resting angle.

$\theta = \tan^{-1}(h/r)$ $\tan\theta = h / r$

Where,

The angle of repose is represented by θ.

The pile's height is h.

r = the pile's base radius

Table 2 Degree of Repose Angle

Angle of repose (degrees)	Type of flow
< 25	Excellent
25-30	Good
30-40	Moderate flow
> 40	Poor

- *Flow Rate:*

The term "flow rate" refers to the pace at which a material or powder exits the aperture of a funnel with the proper size. The quantity of granules is weighed and poured into a funnel with an 8mm aperture, and a stopwatch is used to record the amount of time it takes for the granules to exit the orifice.

Weight of granules/time in seconds is the flow rate.

- *Bulk Density:*

Bulk density is calculated by dividing the mass of the powder by the bulk volume in cm3. About 50 cm3 of powder is placed into the 100 ml graduated cylinder, and it is allowed to fall three times onto a firm wooden surface at two-second intervals from a height of one inch. After that, the bulk density is determined using the formula below.

The equation for Db is M Vf.

Where

Bulk density is represented by Db.

The weight of the samples in grams is denoted by M.

Vf = The cylinder’s ultimate volume of granules in cubic centimetres

- *Tapped Density:*

Dividing a powder's mass by its tapped volume in cubic centimetres yields its tapped density. About 50 cm3 of the powder sample, which had previously been run through a standard sieve no. 20, must be carefully placed into a 100 ml graduated cylinder. From a height of one inch, the cylinder must fall 100 times onto a hard wood surface every two

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seconds. The tapped density of each mixture may then be calculated by dividing the weight of the sample in grams by the ultimate tapped volume in cubic centimetres of the sample in the cylinder. The formula for tapped density is as follows:

$Db = M\ Vf$

Where

Bulk density is denoted by the symbol Db.

Weight of samples in grams is represented by M.

The last number of granules in cm3 is represented by Vf.

➢ *Carr's Index:*

The indirect technique of assessing powder flow from bulk density is known as Carr's Index, or Carr's compressibility index, which was created by Carr. The percentage compressibility of a powder is a direct indicator of its ability to support a potential powder arch or bridge. The following equation allows one to compute Carr's index for each composition:

Where,

Poured bulk or bulk density is referred to as D2.

Bulk density that is tapped or consolidated is known as D1.

Evaluation of Effervescent Tablets Weight variation: Twenty tablets from every batch is randomly selected to check their uniformity. These tablets are weighed individually, and their avg. weight is calculated. From this average

Table 3 Carr's Index

Carr's index (%)	Type of flow
5-15	Excellent
12-16	Good
18-21	Fair
23-28	Slightly Poor
28-35	Poor
35-38	Very Poor
>40	Extremely poor

IV. EVALUATION OF EFFERVESCENT TABLETS

➢ *Organoleptic Properties*

Effervescent tablets are evaluated for their organoleptic qualities using a variety of methods, such as visual inspection for colour, shape, and consistency; Odour assessment for the unique scent of active ingredients; and taste evaluation for effervescent response and overall palatability. These tests make sure that the tablets meet the necessary quality requirements and provide consumers with a pleasant sensory experience.

➢ *Weight Variation [48]*

To ensure consistency, twenty pills are chosen at random from each batch. Each tablet is weighed separately, and the average weight is determined. The percent deviation for each tablet is calculated using this average weight. The maximum allowed weight fluctuation as per USP and I.P is stated below (Table 4).

Table 4 Weight Variation Specification.

IP/BP	Limit	USP
80 mg or less	10%	130mg or less
More than 80mg or less than 250mg	7.5%	130mg to 324mg
250mg or more	5%	More than 324mg

➢ *Diameter and Thickness of the Tablet*

The uniformity of tablet size depends on the tablet's diameter and thickness. Vernier callipers are used to measure it.

➢ *Tablet Hardness*

The resistance of tablets is often determined by the hardness of the tablet, which is a crucial consideration because the tablet might break during transportation, storage, or handling if it is not hard enough. The hardness of a tablet is determined using a Monsanto hardness tester. In kg or N, hardness is measured.

➢ *Friability (F)*

Tablet friability assessed using Roche friabilator. In a plastic chamber spinning at 25 rpm and lowering a tablet at a height of 6 inches per revolution, this unit exposes the tablet to the combined effect of abrasion and shock. Pre-weighted tablet samples were put in the friabilator and the 100 revolutions were subjected to them. Tablets were dusted and weighted back using a soft muslin fabric. The cap for USP is 0.5 to 1 percent. Friability (F) is given by the equation. An average of three calculations must be stated for each formulation.

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➢ *Measuring the Time, it Takes for Effervescence to Occur:*

Place one tablet in the beaker with 200 ml of water at a temperature of 20°C ± 1°C to determine the effervescence time. The time the tablet is placed in the beaker should be recorded using a stopwatch. The final time is recorded when the tablet is completely dissolved or when the clear solution is produced. Each formulation should have a mean of about three tablets measured.

➢ *Effervescent Solution pH Determination*

Use a pH meter to check the pH of the solution as soon as the tablet has finished dissolving. The average of three measurements is used.

➢ *CO2 Concentration Measurement*

The weight changes are measured after placing one tablet in 100 ml of 1N sulfuric acid. The discrepancy is in the quantity (mg) of carbon dioxide in one tablet. The measurement of three pills is considered.

➢ *The Amount of Moisture*

Desiccators containing activated silica gel are used to dry 10 tablets, allowing them to stay for 4 hours. For effervescent tablets, a moisture content of 0.5% or less is permitted.

➢ *Content Uniformity:*

Ten tablets were selected at random. Using a 50 mL volumetric flask and a phosphate buffer of pH 6.8, each tablet was transferred, dissolved, and diluted to 50 mL. In a 100 mL solution, one millilitre of this solution was diluted with phosphate buffer pH 6.8. The quantity of medication present in each tablet was determined by UV spectroscopy at 246 nm. Material uniformity is commonly limited to this level.

- IP: -Active at less than 10% or 10 mg
- BP: Less than 2% or 2 mg of activity
- USP: - Active at a concentration of less than 25 mg or 25 percent.

NMT 10 tabs are allowed, with a deviation of 85–115% and no outside 75–125% of the average value/IP/BP/USP (relative standard deviation less than or equal to 6%).

If 2 or 3 single values fall outside the range of 85–115% of the average value, and if no values fall outside the range of 75–125% for 20 pills.

➢ *Effervescence Time/ Disintegration Time:*

To test the disintegration of tablets, as stated in IP, place a beaker containing 250 ml of water between 20 and 30 degrees Celsius, introduce one tablet, and watch the release of CO2 bubbles. The tablet should break apart in five minutes, leaving no lumps or debris. Repeat this process with five more tablets. A tablet is deemed to have failed if it does not break apart within five minutes, unless the tablet's particular instructions specify differently.

➢ *The Test of Dissolution:*

In an effervescent tablet dissolution experiment, the tablet is immersed in a predetermined amount of water in dissolution apparatus at a specific temperature. The drug concentration in the water is measured at regular intervals using a spectrophotometer or other method, and agitation is caused by the device's paddle or basket rotating. The test is conducted in triplicate, and the findings are compared against the applicable standards for quality and effectiveness [49].

V. CONCLUSION

Effervescent tablets have emerged as a valuable and patient-friendly dosage form within modern pharmaceutical technology, offering a unique combination of rapid disintegration, enhanced solubility, improved palatability, and superior patient compliance compared to conventional solid oral forms. Their mechanism is fundamentally driven by an acid–base reaction that releases carbon dioxide, enabling fast dispersion in water and overcoming swallowing difficulties commonly experienced by paediatric, geriatric, and dysphagic patients. This review highlights that the successful development of effervescent tablets requires careful consideration of excipient selection, as components such as acids, alkalis, sweeteners, binders, flavouring agents, and water-soluble lubricants play crucial roles in ensuring stability, mechanical integrity, and sensory acceptability. Manufacturing of effervescent tablets demands strict environmental control due to their extreme sensitivity to moisture. Techniques such as wet granulation, dry granulation, direct compression, hot-melt granulation, and fluid-bed processing offer diverse advantages depending on formulation needs, equipment availability, and product characteristics. Each technique must be optimized to prevent premature effervescent reactions and to achieve desirable tablet properties such as adequate hardness, low friability, and uniform dispersion. Advanced technologies, including vacuum-assisted drying, melt extrusion, and even 3D printing, continue to expand possibilities for more efficient and innovative effervescent formulations. Evaluation parameters—including weight variation, hardness, friability, effervescence time, pH, CO_2 content, moisture content, and drug content uniformity—are essential to ensure safety, stability, and therapeutic performance. While effervescent tablets offer notable advantages such as rapid onset of action, improved bioavailability, and enhanced patient satisfaction, challenges remain in terms of production cost, packaging requirements, and the need for specialized environmental controls. Overall, effervescent tablets represent a versatile and evolving dosage form with significant potential for both pharmaceutical and nutraceutical applications. Continued research in formulation optimization, moisture-resistant technologies, and advanced manufacturing methods will further strengthen their role in delivering safe, effective, and patient-centric therapies.

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