Volume 9, Issue 11, November– 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV945

Modern Approaches to Quality Assurance of Drug Formulation

Satyam Singh[1]; Dr Swarup J. Chatterjee[2]; Vishwanath Dubey[3]
S.N. College of Pharmacy Babupur Jaunpur.

Abstract:- Development of the pharmaceutical science have gone through amazing change over the past two decades, and modern technologies continue to transform QA process in drug formulation. considering the importance of ensuring the quality, safety, and efficacy of pharmaceutical products, it is now essential that the evolution of QA methodologies and techniques, especially these accelerate through automation analytics and regulatory frameworks, become important to this end. This review highlight the convince in QA of drug formulation, with more focus on latest trends such as "quality by design", process analytical technology and advance analytical techniques like spectroscopy, chemometrics, and artificial intelligence.

Keywords:- *Safety Standards, Quality Test, Continuous Improvement, Minimize Risk, Design Planning.*

I. INTRODUCTION

Quality assurance in drug formulation can be consider as the lifeblood of ensuring that pharmaceutical product meet good safety, efficacy, and quality standards. Historically, QA depend on end-product testing. Over recent years though, it has develop to stronger, data-driven and dynamic approaches. This is not only conformity with regulations but more generally allowing placing quality in the product's lifecycle, right from development up to manufacturing.

II. LITERATURE SURVEY

➢ *Quality by Design (QbD)*

QbD is a science for drug development which focuses on building quality into the product rather than testing the product for its quality afterwards. It involves understanding the process:

Generally, identifying the critical Quality Attributes (CQAs) and Critical process parameters (CPPs) that impact the quality of the product.

- *Risk Management:*

Use risk-based approaches to manage variability and control it.

- *Design Space:*

Defining an acceptably operated range of CPPs to ensure that CQAs are reliably obtained.

The FDA and the EMA, as some of the major regulatory bodies support the QbD approach, which demands that drug manufacturers prove that their processes are designed with quality in mind.

➢ *QbD Involves these main Parts*

- *Experiment Design (DoE):*

A methodical way to study how different factors in the product and its making affect each other.

- *Risk Evaluation:*

Using tools like Failure Mode and Effect Analysis (FMEA) or Fishbone Diagrams to find and reduce risks in the process.

- *Control Plan:*

Setting up checks during the process, key quality attributes (CQAs), and ongoing monitoring to maintain product quality

➢ *Process Analytical Technology*

PAT is one of the essential parts of modern QA concepts. It deals with real-time measurement technologies that monitor and control manufacturing processes. The main objectives of PAT are to maintain process control it ensure safe quality monitoring from raw material obtaining to the final product release.

➢ *The Assumption of PAT Helps:*

- Minimize batch-to-batch variability.
- Identify and address deviations on time.
- Enhance process understanding and control.

- *Minimize Variability:*

The process may be corrected in real-time to achieve drug formulation uniformity. Support for continuous manufacturing: PAT support a more continuous and less-stop production processes. Some of the PAT tools include spectroscopic techniques (near-infrared spectroscopy), chromatography, and real-time microscopy.

➢ *Advanced Analytical Techniques*

Spectroscopy and chemometrics: Spectroscopy combined with chemometric analysis offer very useful non-destructive testing of drug formulations. Techniques, and include Near-Infrared spectroscopy determines blend uniformity, moisture content and tablet coating in real-time

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV945

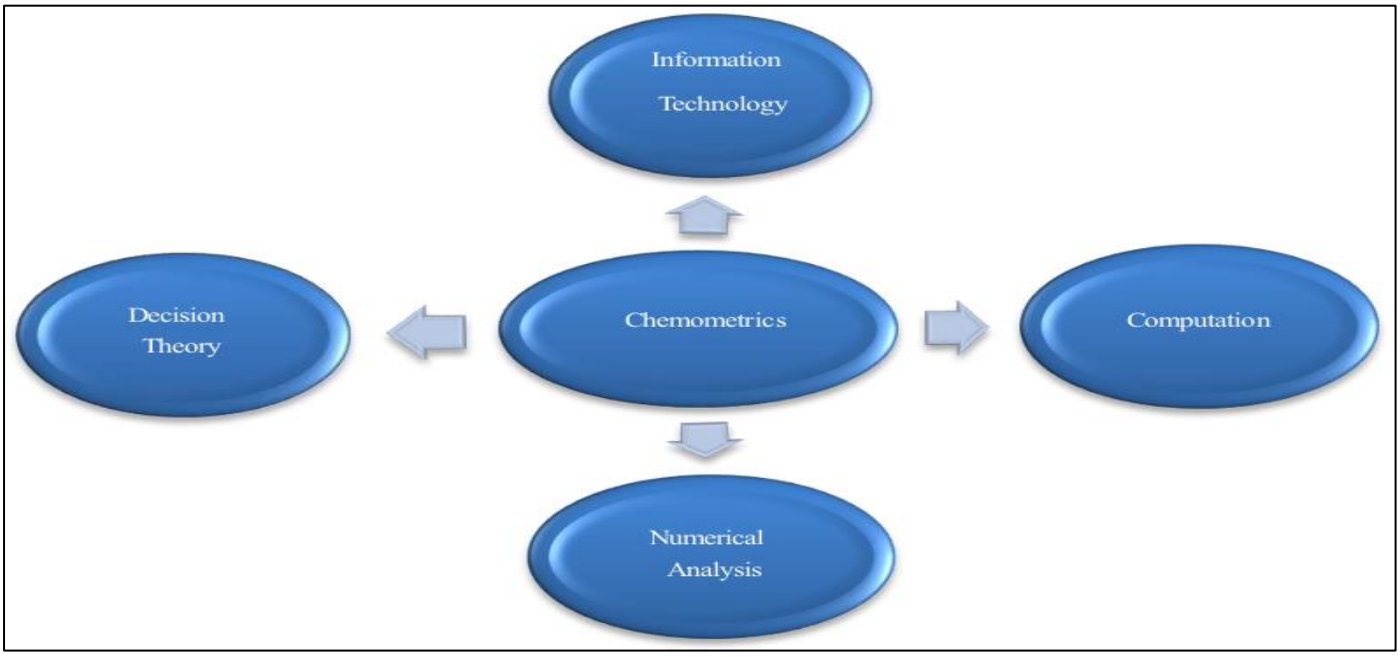

Fig 1 Advanced Analytical Techniques

Raman spectroscopy: Equally useful for raw material identification and final product characterization. Fourier-Transform Infrared spectroscopy: Useful in compatibility studies of APIs with excipients.

4 High Resolution Imaging Techniques: Scanning Electron microscopy (SEM) and (AFM) allow seeing in detail drug particle size, shape, and surface features. The latter features are crucial for the definition of drug's bioavailability and dissolution profile.

- *Application of AI and machine Learning in QA*

AI/Machine learning is being added to the QA system that transform pharmaceutical manufacturing. AI- enabled models can: They will predict result based on large data sets, AI is likely to predict the result on CQAs due to various types of (CPPs) and helps in controlling it more precisely.

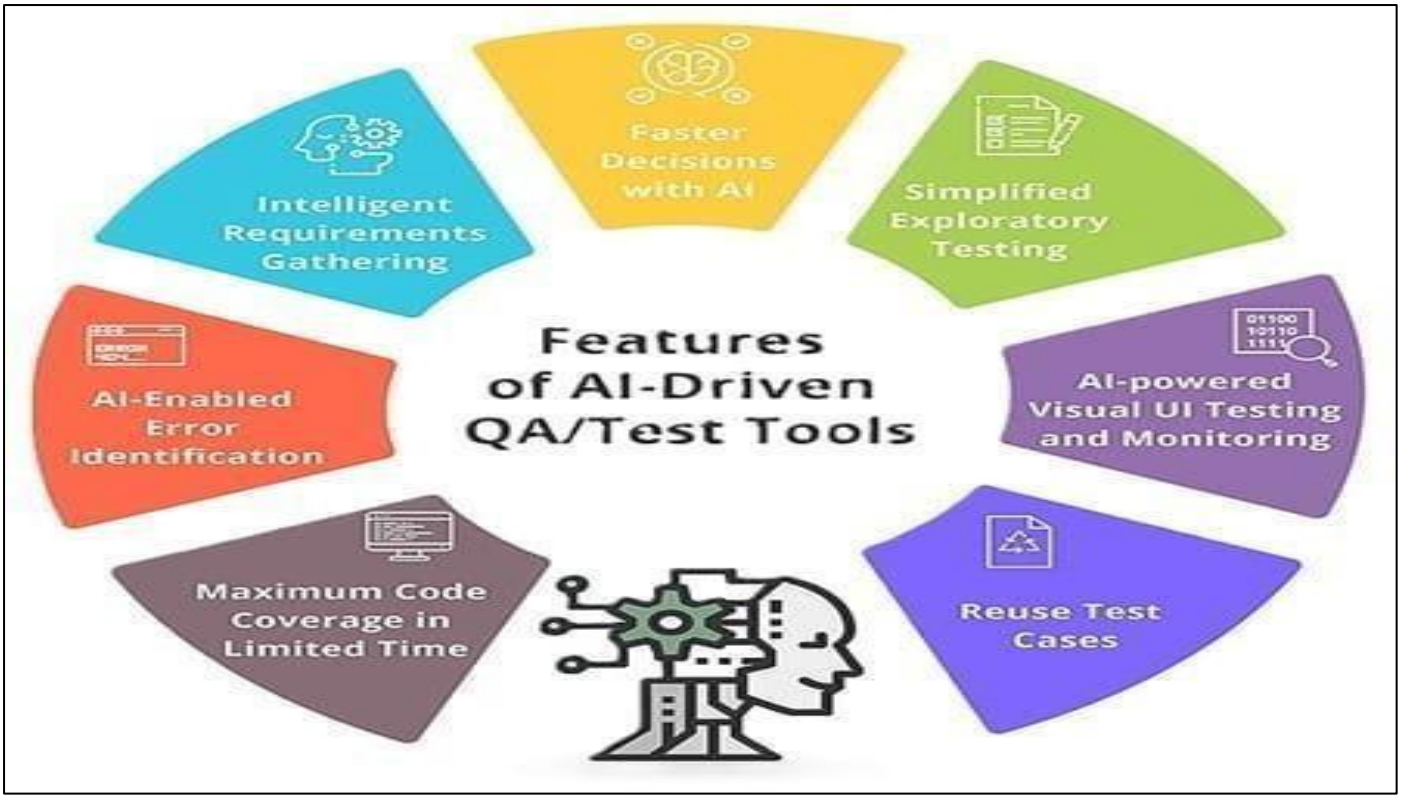

Fig 2 Application of AI and Machine Learning in QA

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV945

- *Process Optimization:*

The ML algorithms can change the manufacturing process in a way that it decreases the chance of human errors and reduce the time consumption.

- *Enhanced Decision -making:*

Data analytics based on real-time data improves support to decision on quality control. Application of AI in QA include early-stage drug discovery, formulation design, and predictive maintenance of manufacturing equipment.

➢ *Continuous Manufacturing*

Continuous manufacturing (CM) is innovation in contrast with traditional batch production. CM provides the following advantages regarding QA benefits. Quality control can be monitored in real time: The PAT system allows instantaneous feedback of quality, and changes can be made without having to stop the production process. Less variability: Continuous processes result in fewer deviations and therefore are capable of holding greater quality and also decrease the chances of batches filing. Greater efficiency: CM avoids the need for frequent stoppages, which increases the speed of production and thus reduces cost. Now, regulatory agencies are becoming more favourable towards adopting CM, as it can add value to the product by improving quality and achieving better efficiency in production.

- *Benefits of Continuous Manufacturing:*

✓ Real-Time Quality Check: With continuous production, we can watch and manage quality as it happens, lowering the chance of mistakes.
✓ Less Inconsistency: By avoiding the stopping and starting of batch production, continuous manufacturing makes products more uniform in quality.
✓ Quicker Production: Continuous manufacturing greatly speeds up the production process, enabling quicker delivery of high-quality items to the market.
✓ Challenges:
✓ Switching to continuous manufacturing involves making large investments in new machinery and technology.
✓ Moving from batch to continuous manufacturing involves rethinking quality control methods and incorporating real-time monitoring tools, such as PAT.

➢ *Regulatory Considerations*

QA during the drug formulation phase must comply with the principles applied in the modern QA. Agencies such as the FDA, EMA, and ICH have provided some basic principles and guidelines in which PQS is outlined to be a framework that will ensure that quality is built into every stage of the lifecycle of the product. Data integrity: The most important aspect of validating the validity and correctness of all data collected as part of the manufacturing process. Lifecycle management: QA practices that are beyond the traditional approval of a product and incorporate post-market surveillance.

➢ *Challenges and Future Directions*

Modular approaches to QA have a number of advantages, but also pose several challenges: On integration of new technologies into traditional processes: In order to introduce AI, PAT, and continuous manufacturing, resources are needed for current processes. Data management: In real time monitoring, AI-based systems produce huge amounts of data; suitable strategies for data management need to be implemented in these areas. Regulatory harmonization: The regional requirements on regulations will pose more challenges in the implementation of QA innovations around the world. Future developments in QA are likely to be concentrated in enhanced automation, more experienced AI algorithms, and the demand for convert treatments that will involve far more individualized quality assurance plans.

➢ *Risk-Based Approaches in Quality Assurance*

In recent years, quality assurance (QA) methods have become more risk-based, where the allocation of assets is based on potential threats to product quality. The FDA and the EMA, amongst others, urge manufacturers to adopt Risk Management (RM) methodologies so that they are assured that the most critical processes are adequately monitored and controlled. There is, however, a set of key tools which are used in the QA process that aim at eliminating any potential risk. These tools include: Failure Modes and Effects Analysis (FMEA): A methodology that is utilized for the purpose of recognizing potential errors and their impact on the product, facilitating the proactive avoidance of them.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV945

Fig 2 Risk-Based Approaches in Quality Assurance

- *Fault Tree Analysis (FTA):*

An image-based device that is employed to gauge the chances of certain errors happening and to recognize the main culprits.

- *Risk-Based Inspections:*

Specialized examinations aimed at the points of most risk in the production process which help the authorities and the companies to focus on the most critical areas of concern. Risk- based thinking is a strategy that medical companies could use to more efficiently input more resources into production areas that will have the greatest effect on product quality.

➢ *Risk-Based Methods and ICH Q9 Guidelines*

The International Council for Harmonization (ICH) Q9 guidelines focus on using a risk-based method for quality management. These guidelines suggest that companies should evaluate and reduce risks related to making and producing drugs. The risk-based method means finding important risks that could harm product quality and putting controls in place to lower those risks. Including risk management in quality assurance processes helps focus on the most important areas, making sure the biggest risks to product quality are handled. This method fits with the QbD idea, making risk management a key part of current quality assurance.

➢ *Examples of Modern Quality Assurance in Drug Companies*

Many drug companies have used new quality assurance methods effectively. For instance, a big international drug company combined QbD and PAT in making tablets. This helped lower the differences in their products and made the whole process better. Another example is using AI for predicting when machines need maintenance. This cut machine downtime by 30%, allowing more products to be made.

These examples show how new quality assurance methods can greatly improve both the quality of drugs and how well the production process works.

III. CONCLUSION

Modern approaches to the QA process of drug formulation are one massive step forward towards ensuring that the product produced, drug formulation-wise, will have many aspect which can ensure quality, safety, and efficacy. Now, technologies like QbD, PAT, AI, and continuous manufacturing in drug formulation change the pattern from reactive to proactive quality control. This will be a great hurdle for the pharmaceutical industry to enjoy such high standards and full fill regulatory demands with innovation. References Include relevant journal articles, regulatory guidelines, and any other resource consulted to inform the review. This is a comprehensive structural outline of the advanced approaches in QA on formulation-related drug issues, reflecting the paramount role of innovation for constant quality and compliance guarantees in the pharmaceutical sector.

REFERENCES

[1]. Juran JM. Juran on quality by design: the new steps for planning quality into goods and services. New York (NY): Simon and Schuster; 1992.
[2]. Woodcock J. The concept of pharmaceutical quality. Am Pharm Rev. 2004;7(6):10–15.
[3]. Awotwe-Otoo D, Agarabi C, Wu GK, et al. Quality by design: impact of formulation variables and their interactions on quality attributes of a lyophilized monoclonal antibody. Int J Pharm. 2012;438(1):167–175.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV945

[4]. Charoo NA, Shamsher AA, Zidan AS, et al. Quality by design approach for formulation development: A case study of dispersible tablets. Int J Pharm. 2012;423(2):167–178.
[5]. Park S-J, Choo G-H, Hwang S-J, et al. Quality by design: screening of critical variables and formulation optimization of Eudragit E nanoparticles containing dutasteride. Arch Pharm Res. 2013;36(5):593–601.
[6]. Verma S, Lan Y, Gokhale R, et al. Quality by design approach to understand the process of nano suspension preparation. Int J Pharm. 2009;377(1):185–198.
[7]. Group IEW, editor ICH Harmonized tripartite guideline. Pharmaceutical development Q8 (R2). International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use; 2009.
[8]. Li Z, Cho BR, Melloy BJ. Quality by design studies on multi-response pharmaceutical formulation modeling and optimization. J Pharm Innov. 2013;8(1):28–44.
[9]. Elder D, Teasdale A. ICH Q9 quality risk management. In: Teasdale A, Elder D, Nims RM, editors. ICH quality guidelines: an implementation guide. Hoboken, NJ, USA: John Wiley & Sons, Inc.; 2017. p. 579–610.
[10]. Pogány J. ICH pharmaceutical quality system Q10. WHO Drug Information. 2008;22(3):177–181.
[11]. Guideline ICH. Development and manufacture of drug substances (chemical entities and biotechnological/biological entities) Q11. London, United Kingdom: European medicines agency; 2011.
[12]. Lowenborg M. Quality-by-design: the good, the bad, the inevitable: drug development & delivery; 2014 [cited 2018 Jan 23] Available from: http://www.drug-dev.com/Main/Back- Issues/QUALITYBYDESIGN-QualitybyDesign-The-Good-The-Bad-T-768.aspx (open in a new window)
[13]. Sangshetti JN, Deshpande M, Zaheer Z, et al. Quality by design approach: regulatory need. Arab J Chem. 2014;10(Suppl. 2):S3412–S3425. (Open in a new window)Google Scholar
[14]. Plackett RL, Burman JP. The design of optimum multifactorial experiments. Biometrika.1946;33(4):305–325. (Open in a new window) Web of Science ®(Open in a new window)Google Scholar
[15]. Zhang L, Mao S. Application of quality by design in the current drug development. Asian J Pharm Sci. 2017;12(1):1–8 (Open in a new window)PubMed (Open in a new window)Web of Science ®
[16]. Box GEP, Wilson KB. On the experimental attainment of optimum conditions. In: Kotz S, Johnson NL, editors. Breakthroughs in statistics: methodology and distribution. New York, NY: Springer New York; 1992. p. 270–310. (Open in a new window)Google Scholar
[17]. Collins A. Toward a design science of education. New directions in educational technology. NATO ASI series. Vol. 96. Berlin, Heidelberg: Springer Berlin Heidelberg; 1992. p. 15–22. (Open in a new window)Google Scholar
[18]. Yang Y. Multiple criteria third-order response surface design and comparison. Florida: Florida State University; 2008. (Open in a new window)Google Scholar
[19]. Box-Behnken designs: NIST/SEMATECH; 2003 [cited 2018 Jan 23]. Available from: http://www.itl.nist.gov/div898/handbook/pri/section3/pri3362.htm(open in a new window) (Open in a new window)Google Scholar
[20]. Box GEP, Hunter WG, Hunter JS. Statistics for experimenters: an introduction to design, data analysis, and model building. Illustrated ed. Vol. 154. US: Wiley (Wiley Series in Probability and Statistics); 1978. (Open in a new window)Google Scholar
[21]. Araujo PW, Brereton RG. Experimental design II. Optimization. TrAC Trends Anal Chem. 1996;15(2):63–70. (Open in a new window)Web of Science ®(Open in a new window)Google Scholar
[22]. Doornbos DA, De Haan P. Optimization techniques in formulation and processing. In: Swarbrick J, Jc B, editors. Encyclopedia of pharmaceutical technology. Vol. 20. Suppl. 3. New York (NY): Marcel Dekker, Inc.; 2001. p. 77–160. (Open in a new window)Google Scholar
[23]. Pinto J, Podczeck F, Newton J. Investigations of tablets prepared from pellets produced by extrusion and spheronisation. II. Modelling the properties of the tablets produced using regression analysis. Int J Pharm. 1997;152(1):7–16. (Open in a new window)Google Scholar
[24]. Podczeck F. The development and optimization of tablet formulations using mathematical methods. In: Alderborn G, Nyström C, editors. Pharmaceutical powder compaction technology. New York (NY): Informa HealthCare; 1996. p. 561–593. (Open in a new window)Google Scholar
[25]. Chatchawalsaisin J, Podczeck F, Newton JM. The influence of chitosan and sodium alginate and formulation variables on the formation and drug release from pellets prepared by extrusion/spheronisation. Int J Pharm. 2004;275(1):41–60. (Open in a new window)PubMed(Open in a new window)Google Scholar
[26]. Lewis GA, Mathieu D, Phan-Tan-Luu R. Pharmaceutical experimental design. New York (NY): CRC Press; 1998. (Open in a new window)Google Scholar
[27]. Scheffé H. Experiments with mixtures. J Roy Stat Soc Series B (Methodol). 1958;2(2):344–360. (Open in a new window)Google Scholar
[28]. Taguchi G, Ap O. Introduction to quality engineering: designing quality into products and processes. Unipub/Quality Resources; 1986. (Open in a new window)Google Scholar
[29]. Lewis G. Non classical experimental designs in pharmaceutical formulation. Drug Dev Ind Pharm. 1991;17(12):1551–1570. (Open in a new window)Web of Science ®(Open in a new window)Google Scholar

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV945

[30]. Wehrlé P, Palmieri G, The Taguchi's SA. performance statistic to optimize theophylline beads production in a high-speed granulator. Drug Dev Ind Pharm. 1994;20(18):2823–2843. (Open in a new window)Web of Science ®(Open in a new window)Google Scholar
[31]. Chariot M, Lewis G, Mathieu D, et al. Experimental design for pharmaceutical process characterisation and optimisation using an exchange algorithm. Drug Dev Ind Pharm. 1988;14(15– 17):2535–2556.