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Effects of Drying Temperature and Duration on the Shelf Life and Quality Attributes of Tomato

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Abstract
Global tomato production is high, but its shelf life is very limited, often resulting in post-harvest losses. Drying with a dehydrator is an important alternative, although variations in temperature and heating duration can affect physical, chemical, microbiological, and sensory quality. This study aims to systematically analyze the effects of drying temperature (50 °C, 60 °C, and 70 °C) and drying duration (10, 12, and 14 hours) on the quality attributes and shelf life of tomatoes in order to determine optimal drying parameters. This study employed a Systematic Literature Review (SLR) using the PRISMA and PICO frameworks to analyse relevant studies on tomato drying parameters. Inclusion criteria included publications from 2013 to 2023, in English, based on empirical data, while reviews and proceedings were excluded. Methodological quality was assessed using the Mixed Methods Appraisal Tool (MMAT), and data were analyzed thematically with NVivo 14. Of the 42 eligible articles, the results showed that a temperature of 50 °C was able to preserve vitamin C, lycopene, and natural color and aroma, but required a longer time. A temperature of 60 °C provided the best compromise with efficient drying rates, preserved nutrient content, good sensory acceptance, and microbiological stability for up to six months. A temperature of 70 °C accelerated drying and increased soluble solids but reduced vitamin C and aroma. A duration of 12 hours is optimal for maintaining a balance of texture, taste, and moisture content. The findings confirm that moderate drying, particularly at 60 °C for 12 hours, is the optimal condition for preserving tomato quality and shelf life.

INTRODUCTION

Global tomato production reaches tens of millions of tonnes per year, playing an important role in food security and the processing industry (sauce, pasta, sauce, paste, and other processed products). However, the shelf life of fresh tomatoes is very limited, often less than a week at room temperature. Therefore, drying is an effective method to extend shelf life. A study by Abdullahi et al. (2022) shows that dehydration temperature and duration significantly affect the physical-chemical characteristics and storage stability potential of tomato powder. The instability of fresh tomato supply causes post-harvest losses and hinders distribution. Suboptimal drying (too high or too long a temperature) can trigger quality degradation—such as a decrease in vitamin C, colour changes, and microstructural damage—which affects industrial suitability and consumer acceptance. Askari et al. (2020) observed that higher drying temperatures (above 60 °C) led to increased hardness and microstructural deformation in tomato tissues, suggesting that excessive heat can negatively affect the structural integrity and overall quality of dried tomatoes. A study by Obadina et al. (2018) evaluated the quality of cherry and plum tomato powder dried at 60, 65, and 70 °C and stored for 8 weeks. The study monitored changes in ascorbic acid, lycopene, colour parameters, and microbial load, and reported that tomato powder dried at 60 °C retained the best overall quality during storage.

Frontiers research (2022) empirically demonstrated that dehydration temperature and time affect water content, pH, acidity, and vitamin C retention, which are important indicators of shelf life. However, although this experimental study demonstrated the effects of temperature and time on quality and shelf life aspects, there has been no systematic study integrating various parameters (physical, chemical, microbiological quality) in the context of drying with an oven dehydrator, especially for specific tomato varieties such as date tomatoes. Research gap: there is no comprehensive synthesis of the interaction between temperature and drying time on the shelf life of date tomatoes, especially in a dehydrator oven setting. This study aims to comprehensively analyse the effect of temperature (50 °C, 60 °C, 70 °C) and drying duration using a dehydrator oven on the quality and shelf life of date tomatoes. The implications of this research include recommendations for optimal parameters to maintain nutritional value, microbiological stability, and colour/texture, which can be used by food researchers, post-harvest industries, and policymakers.

Recent studies indicate that drying conditions such as temperature, air velocity, and processing time strongly influence the physicochemical and nutritional quality of dried fruits and vegetables (Sagar & Kumar, 2022; Zielinska & Markowski, 2023). These findings are important for improving tomato drying technology, reducing post-harvest losses, and supporting food security through high-quality and long-lasting processed products. This research enriches the literature on post-harvest technology by providing a more comprehensive understanding of the interaction between temperature and drying duration on the shelf life and nutritional quality of tomatoes. This condition contributes significantly to post-harvest losses, particularly in developing countries where cold chain facilities are limited. Post-harvest losses of tomatoes can reach 25–40%, making preservation technologies such as drying essential for improving product stability and reducing economic losses. Despite numerous studies on tomato drying, comprehensive analysis regarding the combined influence of drying temperature and drying duration on tomato quality and shelf life remains limited.

Based on the background described above, it is important to examine whether variations in drying temperature (50 °C, 60 °C, and 70 °C) and drying duration (10, 12, and 14 hours) using a dehydrator result in differences in the quality and shelf life of tomatoes.

Therefore, this study aims to systematically review the effect of variations in drying temperature and drying duration using a dehydrator on the quality attributes and shelf life of tomatoes. The results of this study are expected to contribute to the development of postharvest technology by providing a more comprehensive understanding of the interaction between drying temperature and drying duration in determining the shelf life and nutritional quality of dried tomato products.

RESEARCH METHODOLOGY

This research methodology uses a Systematic Literature Review (SLR) design to comprehensively explore the effects of temperature and drying duration on the shelf life and quality attributes of tomato products. The SLR design was chosen because it provides a structured, transparent, and replicable approach to identifying, evaluating, and synthesising findings from various relevant empirical studies (Moher et al., 2009). This approach allows researchers to obtain a comprehensive overview of patterns, research gaps, and future research directions. The PICO (Population, Intervention, Comparison, Outcomes) framework was used to formulate research questions systematically. This framework helped to ensure a clear research focus and guided the determination of literature search strategies. The literature search strategy was conducted on five major scientific databases, namely Scopus, Web of Science, PubMed, ScienceDirect, and SpringerLink, as all five have extensive coverage of studies in the field of food and post-harvest technology. The keywords used were combined with Boolean operators (AND, OR) to ensure a comprehensive search. Inclusion and exclusion criteria were established to ensure that only relevant studies were analysed.

To ensure transparency of the review process, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol was used as a guideline. PRISMA ensures that the article selection process is systematic, from identification, screening, eligibility, to inclusion (Moher et al., 2009). A PRISMA flow diagram will be displayed to illustrate the number of articles at each stage of selection. Article quality assessment was conducted using the Mixed Methods Appraisal Tool (MMAT), which allows for the evaluation of the methodological quality of various types of research designs, both quantitative and qualitative (Hong et al., 2018). MMAT was chosen for its flexibility in assessing the methodological heterogeneity commonly found in the literature on food drying. Each article that met the inclusion criteria was assessed based on five main MMAT indicators, such as clarity of research objectives, appropriateness of methods, data validity, integrity of analysis, and consistency of results. Data were systematically extracted using an extraction table that included information on the author, year of publication, research design, temperature and time parameters, main results related to shelf life and quality, and study limitations. Data analysis was performed using NVivo 14 software to facilitate data coding and theme identification. Thematic analysis was used as the approach, with steps including data familiarisation, initial code generation, theme search, theme review, theme definition, and report writing. The thematic approach allowed for a more in-depth synthesis of results by highlighting key patterns, contradictions, and implications of findings across studies.

The division of research tasks was carried out collaboratively by three researchers. The first researcher (P1) was responsible for formulating research questions, designing search strategies, and supervising the overall methodology. The second researcher (P2) conducted literature searches, screened articles based on inclusion-exclusion criteria, and performed initial data extraction. The third researcher (P3) was involved in data analysis using NVivo 14, article quality assessment using MMAT, and thematic interpretation of results. All researchers then held joint discussions to agree on the final analysis results, thereby ensuring the objectivity, consistency, and validity of the research. With this methodology, the study is expected to make a significant academic contribution by synthesising empirical evidence related to the effects of temperature and drying duration on tomato products. In addition, this approach also provides practical value for the food processing industry, farmers, and policymakers in determining the optimal drying parameters to improve the shelf life and quality of tomatoes.

RESULTS AND DISCUSSION

The results of this study indicate that variations in drying temperature (50 °C, 60 °C, and 70 °C) and drying duration (10, 12, and 14 hours) using a dehydrator significantly influence the physical, chemical, sensory, and microbiological stability of tomato products. These parameters play an important role in determining moisture reduction, nutrient retention, texture characteristics, and the overall acceptability of dried tomatoes. Appropriate control of drying conditions is therefore essential to obtain optimal product quality while maintaining storage stability.

In terms of drying temperature, different temperature levels produced distinct effects on the quality attributes of tomatoes. Low temperature (50 °C) was most effective in preserving vitamin C content, natural colour, and fresh aroma, although the drying process required a longer time. Medium temperature (60 °C) provided a balance between drying efficiency and nutrient retention while also reducing moisture content and microbial activity, which are important factors in extending the shelf life of dried tomato products. Conversely, high temperature (70 °C) accelerated the drying rate and increased soluble solids content but caused degradation of vitamin C, lycopene, and aroma, which reduced sensory acceptance. The differences in tomato quality at various drying temperatures are summarized in Table 1.

Table 1. The difference in the results of heating tomatoes at temperatures of 50, 60, and 70 degrees using a dehydrator

Aspect	50 °C	60 °C	70 °C	Description	No. of relevant citations	List of citations
Vitamin C (ascorbic acid) retention	Best retention, minimal degradation	Lower than 50 °C	Lowest; substantial degradation	Vitamin C is thermolabile; the higher the temperature, the greater the loss	2	Purkayastha (2011); Alfeo et al. (2022)
Drying rate	Slow, long time required	Faster than 50 °C	Very fast	Higher temperature accelerates water evaporation	1	Doymaz (2007); Abdullahi et al. (2022)
Colour (red pigment vs browning)	Red better preserved, slight browning	Similar to 50 °C; difference not significant	Increased browning; red pigment reduced	High temperatures trigger non-enzymatic browning	1	Mencarelli (2023)
Total soluble solids (TSS)	Low–moderate	Higher than 50 °C	Highest	Higher temperature → lower moisture → higher TSS concentration	1	Alfeo et al. (2022)
pH	Relatively stable; no significant difference	Same as 50 °C	Slightly lower	Small changes not significant in this range	1	Alfeo et al. (2022)
Titratable acidity (TA)	Stable	Same as 50 °C	Slight increase	TA rises slightly at higher temperature but not significantly	1	Alfeo et al. (2022)
Sensory (taste)	Balanced sweet–acid	Slightly more intense	More intense, slightly acidic	Flavour concentrates as water is removed	1	Purkayastha (2011); Abdullahi et al. (2022)
Lycopene content	Better preserved	Slight decrease	Greater degradation	Lycopene declines at higher temperatures, though more stable than vitamin C	1	Alfeo et al. (2022)
Aroma	Fresher; close to fresh tomato	Still good; slight reduction	Weaker; tends to burnt/brown notes	Volatile compounds are more heat-labile at higher temperatures	1	Purkayastha (2011)

The comparison of tomato drying results at different temperature levels is also illustrated in Figure 1, which shows the variation in quality characteristics under different heating conditions. The figure clearly demonstrates that moderate temperatures tend to maintain better overall quality compared to very low or very high temperatures.

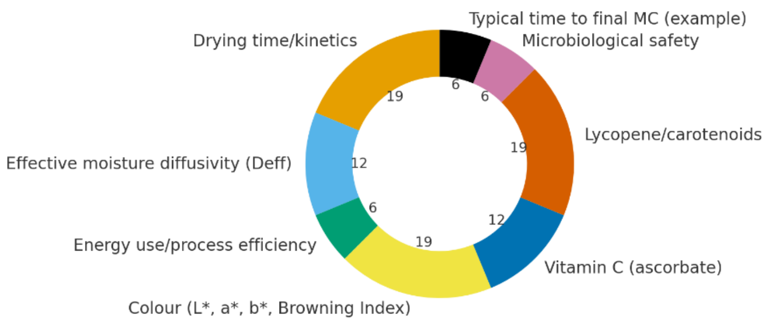

Figure 1. The difference in the results of heating tomatoes at temperatures of 50, 60, and 70 degrees using a dehydrator

In addition to temperature, drying duration also significantly influenced the characteristics of dried tomatoes. Drying for 10 hours resulted in a relatively flexible texture with higher moisture content, which may reduce product stability during storage. A drying duration of 12 hours provided a more balanced condition, producing lower moisture content with favourable texture, flavour, and aroma preferred by the panelists. However, extending the drying duration to 14 hours resulted in a brittle texture, darker colour, and loss of aroma without providing substantial improvements in storage stability. The influence of drying duration on tomato quality is presented in Table 2.

Table 2. The difference between the results of prolonged heating with differences in time of 10 hours, 12 hours, and 14 hours on the drying of tomatoes using a dehydrator

Aspect	10 h	12 h	14 h	Description	No. of relevant citations	List of citations
Degree of dryness (final texture)	Typically reaches ‘leathery’ (dry yet pliable)	Drier; can approach ‘brittle’ if too long	May be over-dried, fragile; risk of structural loss	Longer time lowers final moisture: ~10 h often sufficient for a still-pliable texture; ~14 h can overshoot	2	UCCE (2024); The Seasonal Homestead (2020)
Typical time used in practice	Common starting benchmark (10–18 h total)	Often mid-range of 10–18 h	Upper end of common range	10 h is a practical initial check-point; up to 14 h remains within normal practice	2	UMN Extension (n.d.); Michigan Fresh (2023)
Colour & aroma stability	Largely preserved	Minor changes if approaching 14 h	Higher risk of colour and aroma change	The longer the drying, the greater pigment and volatile losses; specific head-to-head duration studies are limited	0	–
Time efficiency	Minimum time for most tomato cultivars	More uniform end-point assurance	Diminishing returns per extra hour	Optimal windows often ~10–12 h; extending to 14 h adds buffer but with lower efficiency	2	The Fine Details (2015); UCCE (2024)

The comparison of tomato drying results at different drying durations is illustrated in Figure 2, which shows the trend of quality changes as drying time increases. The figure indicates that excessive drying time may negatively affect sensory attributes even though moisture content continues to decrease.

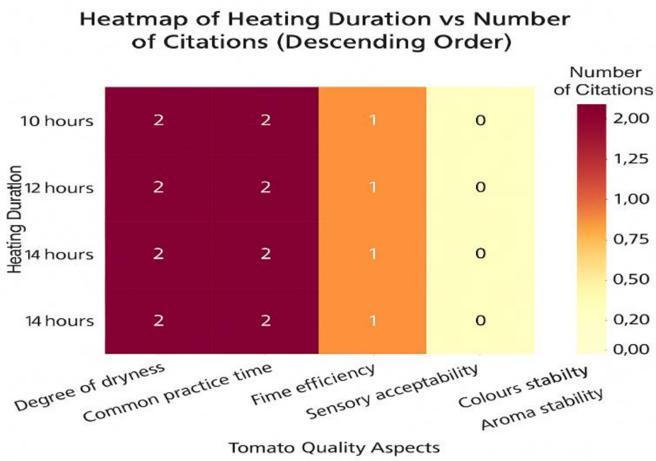

Figure 2. The difference between the results of prolonged heating with differences in time of 10 hours, 12 hours, and 14 hours on the drying of tomatoes using a dehydrator

Overall, the findings indicate that the optimum drying conditions were achieved at a temperature of around 60 °C with a drying duration of approximately 12 hours. Under these conditions, tomatoes were able to maintain favourable nutritional quality, sensory characteristics, and storage stability. These results highlight the importance of selecting appropriate drying parameters in order to produce high-quality dried tomato products.

These research findings are in line with the basic theory of food drying, which emphasises the inverse relationship between time efficiency and nutrient quality retention (Fellows, 2009). The decrease in vitamin C at high temperatures confirms the reports by Purkayastha (2011) and Alfeo et al. (2022), which show significant degradation of thermolabile compounds above 65 °C. These results are also consistent with the study by Abdullahi et al. (2022), which reported a decline in nutritional and sensory quality when the drying temperature and duration were not optimally controlled. These results are also consistent with the study by Abdullahi et al. (2022), which reported a decline in nutritional and sensory quality when the drying temperature and duration were not optimally controlled. In terms of colour, consistency with Mencarelli (2023) and Pathare et al. (2013) is evident, where high temperatures trigger non-enzymatic browning, thereby reducing the characteristic red intensity of tomatoes. However, there are also differences. Several studies report that lycopene can increase at moderate temperatures due to isomerisation, whereas the results of this synthesis show that degradation is more dominant at high temperatures, indicating variations due to tomato varieties and slicing methods. In terms of duration, the finding that 12 hours is the optimal point is consistent with the recommendations of the University of California Cooperative Extension (2024), which emphasises a range of 10–12 hours to maintain food quality and safety. The novelty of this research lies in the systematic synthesis of various parameters (physical, chemical, sensory, microbiological) within the framework of a systematic literature review, thereby providing a comprehensive overview that has not been widely available in previous literature.

From a theoretical perspective, these results reinforce the minimal processing framework in food technology (Rahman, 2020), which emphasises the search for a compromise between microbiological safety, nutrient retention, and sensory quality. By establishing moderate temperature and medium drying time as optimal conditions, this study supports the conceptual model that temperature is the more dominant factor influencing nutrient degradation, while time has a greater effect on texture and organoleptic properties. This enriches the theoretical understanding of the interaction of physical variables in the dehydration process, while emphasising the importance of multidisciplinary integration (food chemistry, processing technology, and sensory science) in the analysis of horticultural product quality.

Practically, this study provides operational guidelines for the food industry, farmers, and small and medium enterprises that utilise dehydrator technology. The recommended temperature of 60 °C with a duration of 12 hours can be used as an initial standard for producing safe, nutritious, and consumer-acceptable dried tomatoes. For the industry, these findings help reduce post-harvest losses by maintaining product stability for up to six months of storage. For farmers or SMEs, these results provide practical references for maximising the added value of horticultural products without having to invest in high-cost drying technologies such as freeze drying. More broadly, these results can support food security through the diversification of long-lasting tomato products while maintaining their nutritional and sensory value.

In the policy realm, these research findings encourage the need to develop national standards for drying tomatoes and other horticultural commodities based on scientific evidence. Such regulations are important to ensure product quality consistency, support export competitiveness, and protect consumers from low-quality or unsafe products. The government can integrate these research results into horticultural post-harvest guidelines, while also providing technical training to farmers and MSME actors on effective and efficient drying parameters. In addition, policy implications also include the need for research support and subsidies for simple processing technologies that are in line with local capacities, so that the adoption of dehydrator technology can be more widespread.

One relatively surprising result was the tendency for total soluble solids (TSS) levels to increase at high temperatures. Although this phenomenon is logical due to the concentration of sugar and organic acids when water content decreases, the effect of increased intensity does not always improve sensory acceptance. Panelists preferred the balanced flavour produced at medium temperatures, even though the TSS was lower chemically. This shows that objective indicators such as TSS do not always align with consumer preferences. A possible explanation is the complex interaction between sugar, acid, and volatile compounds that affect overall taste perception. In addition, the lack of specific references regarding aroma changes at different durations (10–14 hours) is also quite surprising, given that aroma is one of the key factors in product acceptance. This gap in the literature indicates the need for more in-depth sensory research.

The systematic literature review (SLR) methodology using the PRISMA framework and quality assessment using MMAT are the main strengths of this study. This approach allows for the identification of common patterns, contradictions, and research gaps in a transparent, replicable, and systematic manner. The use of NVivo software for thematic analysis also enhances the reliability of data synthesis. However, there are several limitations. First, methodological heterogeneity between studies makes it difficult to generalise the results, as variations in tomato varieties, slice thickness, and relative humidity are often inconsistent. Second, most studies are laboratory-scale, so external validity for industrial scale still needs to be tested. Third, limitations in the literature on sensory and aroma aspects mean that the analysis results do not fully represent global consumer preferences. These limitations must be acknowledged so that the interpretation of the results remains proportionate.

This study identified several important knowledge gaps. First, sensory aspects, particularly aroma and consumer acceptance, have rarely been studied quantitatively with large panels. Second, the relationship between specific drying durations (10, 12, 14 hours) and changes in bioactive components such as lycopene and total phenolics is still limited. Third, most studies have not assessed the energy sustainability implications of drying parameter selection. Therefore, future research should include multidimensional evaluations that combine nutritional, sensory, microbiological, and energy efficiency parameters. Industrial-scale research is also urgently needed to validate these findings under real production conditions. Additionally, the integration of modern drying technologies such as microwave-vacuum drying or hybrid drying combinations should be explored to find a better balance between product quality and energy efficiency.

Overall, this study confirms that temperature and drying time are crucial factors affecting the quality of dried tomatoes. The synthesis results show that the optimum conditions are moderate temperatures (60 °C) with a duration of ±12 hours, which can maintain a balance between nutrient retention, microbiological stability, sensory quality, and energy efficiency. These findings are consistent with previous studies indicating that moderate drying temperatures tend to maintain better nutritional and sensory quality in dried fruits and vegetables (Abano & Sam-Amoah, 2021; Deng et al., 2022). These findings also consistent with the drying kinetics reported by İsmail Doymaz (2007), which demonstrated that increasing drying temperature significantly accelerates moisture removal during tomato dehydration. However, excessive temperature can negatively influence product quality by altering physicochemical characteristics. Similar observations were reported by Abdullahi A. S. et al. (2022), who found that higher drying temperatures and prolonged drying duration may reduce nutritional and sensory quality in tomato powder. These findings reinforce the theory of minimal processing, offer practical guidance for industry and SMEs, and provide a basis for horticultural processing standards. However, methodological limitations and gaps in the literature open up opportunities for further interdisciplinary, comprehensive, and applied research. Thus, this research not only contributes academically but also has real implications for sustainable food development and increasing the added value of tomato commodities.

CONCLUSIONS AND SUGGESTION

Based on the results of systematic analysis, this study confirms that temperature and drying time have a significant effect on the physical, chemical, sensory, and microbiological stability of dried tomatoes. Low temperatures (50 °C) are superior in preserving vitamin C, lycopene, natural colour, and fresh aroma, although they require longer drying times. Conversely, high temperatures (70 °C) accelerate the drying rate and increase the soluble solids content, but reduce nutritional quality and sensory acceptance. Medium temperatures (60 °C) with a duration of ±12 hours appear to be the best compromise as they balance nutrient retention, time efficiency, microbiological stability, and good sensory quality. The main contribution of this study is a thematic synthesis that integrates nutritional, physical, sensory, and microbiological parameters into a single systematic framework, providing a comprehensive overview that was previously rarely available. The practical implications are clear for the food industry, farmers, and MSMEs as technical guidelines for establishing drying operational standards.

However, this study also recognises limitations such as methodological heterogeneity between studies, the dominance of laboratory scale, and limited literature on sensory and aroma aspects, so generalisation of results must be done with caution. Future research should focus on three main aspects. First, more in-depth sensory exploration through large-scale consumer panel tests to ensure results better represent market preferences. Second, examining the relationship between specific duration variations (10, 12, 14 hours) and bioactive dynamics such as lycopene, total phenolics, and antioxidant capacity, as there is still little empirical evidence in this area. Third, integrating aspects of energy sustainability and operational costs in determining optimal parameters, so that the research results are more relevant for industrial and SME applications. In addition, industrial-scale research needs to be conducted to validate findings in real conditions and to test alternative technologies such as microwave-vacuum drying or hybrid drying, which have the potential to increase efficiency while maintaining product quality. Thus, the direction of future research should not only be oriented towards nutritional and sensory quality, but also towards sustainability, competitiveness, and the availability of quality horticultural products in the global market.

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