2025 SYARAT KHUSUS_Moisture Migration_Correspondent History.pdf

Unika Soegijapranata1

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Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Submission received for Food Reviews International (Submission ID: 247748891)

1 message

journalshelpdesk@taylorandfrancis.com <journalshelpdesk@taylorandfrancis.com> Tue, Dec 3, 2024 at 8:13 AM
To: probo@unika.ac.id

37

Taylor & Francis
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Dear Probo Nugrahedi,

Thank you for your submission.

Submission ID	**247748891**
Manuscript Title	**Moisture migration and its prevention in multi-domain bakery products: a review**
Journal	**Food Reviews International**

If you made the submission, you can check its progress and make any requested revisions on the Author Portal

Thank you for submitting your work to our journal.
If you have any queries, please get in touch with journalshelpdesk@taylorandfrancis.com.

Kind Regards,
Food Reviews International Editorial Office

Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Reminder: Food Reviews International

1 message

Food Reviews International <onbehalfof@manuscriptcentral.com> Wed, Mar 26, 2025 at 1:38 PM
Reply-To: LFRI-peerreview@journals.tandf.co.uk
To: probo@unika.ac.id

26-Mar-2025

Dear Dr Probo Nugrahedi:

Recently, you received a decision on Manuscript ID LFRI-2024-0996, entitled "Moisture migration and its prevention in multi-domain bakery products: a review." This e-mail is simply a reminder that your revision is due in two weeks. If it is not possible for you to submit your revision within two weeks, we will consider your paper as a new submission.

Please see a copy of the decision letter below which contains details of how to submit your revision and any comments from the editor/reviewers:

08-Jan-2025

Dear Dr Probo Nugrahedi:

Your manuscript entitled "Moisture migration and its prevention in multi-domain bakery products: a review" which you submitted to Food Reviews International, has been reviewed. The reviewer comments are included at the bottom of this letter.

The reviewer(s) would like to see some revisions made to your manuscript before publication. Therefore, I invite you to respond to the reviewer(s)' comments and revise your manuscript.

When you revise your manuscript please highlight the changes you make in the manuscript by using the track changes mode in MS Word or by using bold or colored text.

To submit a revision, go to https://rp.tandfonline.com/submission/flow?submissionId=247748891&step=1. If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript.

If you have any questions or technical issues, please contact the journal's editorial office at LFRI-peerreview@journals.tandf.co.uk.

Because we are trying to facilitate timely publication of manuscripts submitted to Food Reviews International, your revised manuscript should be uploaded as soon as possible. If it is not possible for you to submit your revision in a reasonable amount of time, we may have to consider your paper as a new submission.

Once again, thank you for submitting your manuscript to Food Reviews International and I look forward to receiving your revision.

Sincerely,
Dr Wu
Associate Editor, Food Reviews International

Comments from the Editors and Reviewers:
There are serious concerns about this manuscript. The authors should sufficiently introduce prior work in the field, improve clarity of the work especially to remove repetitive description, improve comprehensiveness and critique, add necessary figures to help readability.

Reviewer: 1

Comments to the Author
The texture and value of baked products can be affected by moisture migration, making the study of the mechanisms of moisture migration and preventive measures critically important. This review summarizes the mechanisms of moisture migration in baked products, the impact of moisture migration on these products, and strategies to prevent moisture migration. The content of the manuscript is valuable in the field of food science. However, the review section of the article is insufficient, and the number of cited references is relatively limited. In summary, I believe that this manuscript is not suitable for publication in Food Reviews International.

1. Introduction: Insufficient introduction to previous literature research and failure to demonstrate the importance of the content in this article.
2. Moisture migration for multi-domain bakery products: Please provide some figures to help readers better understand the mechanism of moisture migration in baked products.
3. Moisture migration for multi-domain bakery products: Please cite more references. For example, the manuscript cites relatively few references when describing the factors influencing moisture migration, which fails to adequately reflect the key concept of multi-domain baking (includes breads, pastries, cookies, pies, tarts, and cakes) as you mentioned in the Introduction.
4. Please simplify the conclusion.
5. Please add the comparison results between different models and actual experiments in Table 1.

Reviewer: 2

Comments to the Author
It's suggested to add some figures in the text. For example for declaring moisture migration models a schematic fig is highly suggested.
Page 17 line 16: insert Fick's equation in the text.

Reviewer: 3

Comments to the Author
This study reviewed the moisture migration and prevention evaluation in multi-domain bakery products. The paper's repeated paragraphs in more than one place are noteworthy. Other possible changes are shown in the PDF file.

If you have any questions or experience any difficulties submitting your revised manuscript, please contact the journal's editorial office at LFRI-peerreview@journals.tandf.co.uk.

This e-mail is simply a reminder that your revision is due in two weeks. If it is not possible for you to submit your revision within two weeks, we will consider your paper as a new submission.

Sincerely,
Haritha Ravichandiran
Food Reviews International Editorial Office
LFRI-peerreview@journals.tandf.co.uk

Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

247748891 (Food Reviews International) A revise decision has been made on your submission

8 messages

Food Reviews International <onbehalfof@manuscriptcentral.com> Thu, Jan 9, 2025 at 3:30 AM
Reply-To: jwu3@ualberta.ca
To: probo@unika.ac.id

08-Jan-2025

Dear Dr Probo Nugrahedi:

Your manuscript entitled "Moisture migration and its prevention in multi-domain bakery products: a review" which you submitted to Food Reviews International, has been reviewed. The reviewer comments are included at the bottom of this letter.

The reviewer(s) would like to see some revisions made to your manuscript before publication. Therefore, I invite you to respond to the reviewer(s)' comments and revise your manuscript.

When you revise your manuscript please highlight the changes you make in the manuscript by using the track changes mode in MS Word or by using bold or colored text.

To submit a revision, go to https://rp.tandfonline.com/submission/flow?submissionId=247748891&step=1. If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript.

If you have any questions or technical issues, please contact the journal's editorial office at LFRI-peerreview@journals.tandf.co.uk.

Because we are trying to facilitate timely publication of manuscripts submitted to Food Reviews International, your revised manuscript should be uploaded as soon as possible. If it is not possible for you to submit your revision in a reasonable amount of time, we may have to consider your paper as a new submission.

Once again, thank you for submitting your manuscript to Food Reviews International and I look forward to receiving your revision.

Sincerely,
Dr Wu
Associate Editor, Food Reviews International
jwu3@ualberta.ca

Comments from the Editors and Reviewers:
There are serious concerns about this manuscript. The authors should sufficiently introduce prior work in the field, improve clarity of the work especially to remove repetitive description, improve comprehensiveness and critique, add necessary figures to help readability.

Reviewer: 1

Comments to the Author

31 The texture and value of baked products can be affected by moisture migration, making the study of the mechanisms of moisture migration and preventive measures critically important. This review summarizes the mechanisms of moisture migration in baked products, the impact of moisture migration on these products, and strategies to prevent moisture migration. The content of the manuscript is valuable in the field of food science. However, the review section of the article is insufficient, and the number of cited references is relatively limited. In summary, I believe that this manuscript is not suitable for publication in Food Reviews International.

1. Introduction: Insufficient introduction to previous literature research and failure to demonstrate the importance of the content in this article.
2. Moisture migration for multi-domain bakery products: Please provide some figures to help readers better understand the mechanism of moisture migration in baked products.
3. Moisture migration for multi-domain bakery products: Please cite more references. For example, the manuscript cites relatively few references when describing the factors influencing moisture migration, which fails to adequately reflect the key concept of multi-domain baking (includes breads, pastries, cookies, pies, tarts, and cakes) as you mentioned in the Introduction.
4. Please simplify the conclusion.
5. Please add the comparison results between different models and actual experiments in Table 1.

Reviewer: 2

Comments to the Author
It's suggested to add some figures in the text. For example for declaring moisture migration models a schematic fig is highly suggested.
Page 17 line 16: insert Fick's equation in the text.

Reviewer: 3

Comments to the Author
This study reviewed the moisture migration and prevention evaluation in multi-domain bakery products. The paper's repeated paragraphs in more than one place are noteworthy. Other possible changes are shown in the PDF file.

Review-LFRI-2024-0996-Proof-hi.pdf
743K

Probo Y. Nugrahedi <probo@unika.ac.id> Thu, Jan 9, 2025 at 5:31 AM
To: jimmy.perdana@rd.nestle.com, stanley.foodtech@gmail.com, Haniel Yudiar <haniel@unika.ac.id>, Gelbert Jethro Sanyoto <gelbert@unika.ac.id>

Teman2 yb, berikut comments dari reviewers yg harus kita garap a.s.a.p. Trims
Rgrds, pro
[Quoted text hidden]

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Perdana,Jimmy,US-Bridgewater <Jimmy.Perdana@rd.nestle.com> Thu, Jan 9, 2025 at 6:40 AM
To: Frans Tumbuhan <cherfrans@gmail.com>
Cc: "probo@unika.ac.id" <probo@unika.ac.id>

From: Probo Y. Nugrahedi <probo@unika.ac.id>
Sent: Wednesday, January 8, 2025 5:31 PM
To: Perdana,Jimmy,US-Bridgewater <Jimmy.Perdana@rd.nestle.com>; stanley.foodtech@gmail.com; Haniel Yudiar <haniel@unika.ac.id>; Gelbert Jethro Sanyoto <gelbert@unika.ac.id>
Subject: Fwd: 247748891 (Food Reviews International) A revise decision has been made on your submission

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Probo Y. Nugrahedi <probo@unika.ac.id> Thu, Mar 27, 2025 at 7:14 AM
To: Jimmy Perdana <perdana.jimmy@gmail.com>

OmJim,
ini comments dari reviewer. Yg rev 3 commentsnya langsung di file pdf-nya
Thank you
pro

Dr. Probo Y. Nugrahedi
Dept. of Food Technology - Bachelor & Master Program
Faculty of Agricultural Technology - Soegijapranata Catholic University
Semarang - Indonesia
www.unika.ac.id
[Quoted text hidden]

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Jimmy Perdana <perdana.jimmy@gmail.com> Thu, Mar 27, 2025 at 7:13 PM
To: "Probo Y. Nugrahedi" <probo@unika.ac.id>

Maspro, piye yo corone men kita iso ngedit file together. Ono onedrive ora? Men aku iso mbukak seko kene.. edit.. terus ketok langsung neng gonmu. Iki aku coba ngrengreng comment to Editor & reviewer. Untunge ora akeh. Kita coba ae.

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Cheers, J
[Quoted text hidden]

Comments from the Editors and Reviewers.docx
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Probo Y. Nugrahedi <probo@unika.ac.id> Thu, Mar 27, 2025 at 7:22 PM
To: Jimmy Perdana <perdana.jimmy@gmail.com>

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Ketoke ono, nganggo akun sibobbobis@gmail.com

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Jimmy Perdana <perdana.jimmy@gmail.com> Fri, Mar 28, 2025 at 5:54 AM
To: "Probo Y. Nugrahedi" <probo@unika.ac.id>

maspro.. monggo niki aku cek.

Tinggal nambai figure.
J
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Manuscript_Moisture migration bakery_Food Reviews Int_Pro 19.02_J250326 .docx
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Probo Y. Nugrahedi <probo@unika.ac.id> Fri, Mar 28, 2025 at 8:02 AM
To: Jimmy Perdana <perdana.jimmy@gmail.com>

Matur nuwun
Pro
[Quoted text hidden]

Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Revised submission received for Food Reviews International (Submission ID: 247748891.R1)

1 message

journalshelpdesk@taylorandfrancis.com <journalshelpdesk@taylorandfrancis.com> Tue, Apr 8, 2025 at 1:44 AM
To: probo@unika.ac.id

Taylor & Francis
Taylor & Francis Group

Dear Probo Nugrahedi,

Thank you for submitting your revised manuscript.

Submission ID	**247748891**
Manuscript Title	**Moisture migration and its prevention in multi-domain bakery products: a review**
Journal	**Food Reviews International**

If you made the submission, you can check its progress and make any requested revisions on the Author Portal.

Thank you for submitting your work to our journal.
If you have any queries, please get in touch with journalshelpdesk@taylorandfrancis.com.

Kind Regards,
Food Reviews International Editorial Office

Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Food Reviews International - 247748891.R1 - changes required to your submission

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Food Reviews International <onbehalfof@manuscriptcentral.com> Tue, Apr 8, 2025 at 7:24 PM
Reply-To: LFRI-peerreview@journals.tandf.co.uk
To: probo@unika.ac.id

08-Apr-2025

Dear Dr Probo Nugrahedi:

21 Your above referenced manuscript, entitled "Moisture migration and its prevention in multi-domain bakery products: a review" requires some further changes before it is ready for reviewing in Food Reviews International.

Please be informed that we require both clean and tracked version of the manuscript. Hence, please upload both version of the manuscript in the system for further processing.

21 Your submission has been returned to you and is located in your author dashboard, so that you can make the required changes to it and submit it again.

To re-submit your manuscript, please go to your author dashboard at https://rp.tandfonline.com/dashboard/, locate the manuscript and click 'Resume'.

You may contact the Editorial Office if you have further questions.

Sincerely,
Food Reviews International Editorial Office

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Probo Y. Nugrahedi <probo@unika.ac.id>

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journalshelpdesk@taylorandfrancis.com <journalshelpdesk@taylorandfrancis.com> Tue, Apr 8, 2025 at 9:08 PM
To: probo@unika.ac.id

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Dear Probo Nugrahedi,

Thank you for your submission.

Submission ID	**247748891**
Manuscript Title	**Moisture migration and its prevention in multi-domain bakery products: a review**
Journal	**Food Reviews International**

If you made the submission, you can check its progress and make any requested revisions on the Author Portal

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To: probo@unika.ac.id

Taylor & Francis
Taylor & Francis Group

Dear Probo Nugrahedi,

Thank you for submitting your revised manuscript.

Submission ID	**247748891**
Manuscript Title	**Moisture migration and its prevention in multi-domain bakery products: a review**
Journal	**Food Reviews International**

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Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Food Reviews International - Decision on Manuscript ID 247748891.R2

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Reply-To: jwu3@ualberta.ca
To: probo@unika.ac.id
Cc: jwu3@ualberta.ca

26-Sep-2025

Dear Dr Probo Nugrahedi:

Ref: Moisture migration and its prevention in multi-domain bakery products: a review

Our referees have now considered your paper and have recommended publication in Food Reviews International. We are pleased to accept your paper in its current form which will now be forwarded to the publisher for copy editing and typesetting. The reviewer comments are included at the bottom of this letter.

You will receive proofs for checking and copyright transfer instructions directly from the publisher in due course. The publisher also requests that proofs are checked and returned within 48 hours of receipt.

Thank you for your contribution to Food Reviews International and we look forward to receiving further submissions from you.

Sincerely,
Dr Wu
Associate Editor, Food Reviews International
jwu3@ualberta.ca

Reviewer(s)' Comments to Author:

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Accepted Manuscript for this purpose. *Citations received up to 7th August 2024 for articles published in 2019-2023. Data obtained on 7th August 2024, from Digital Science's Dimensions platform, available at https://app.dimensions.ai **Usage in 2021-2023 for articles published in 2019-2023.

Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Your article has been accepted for publication DOI - 10.1080/87559129.2025.2570469

1 message

LFRI-production@journals.taylorandfrancis.com <LFRI-production@journals.taylorandfrancis.com> Wed, Oct 1, 2025 at 11:21 AM
To: probo@unika.ac.id

Dear P Y Nugrahedi,

Congratulations! We are pleased to share that your article "Moisture migration and its prevention in multi-domain bakery products: a review" has been accepted for publication in Food Reviews International.

To move forward with publication, we need you to review and accept the terms and conditions of an author publishing agreement.

We'll start with some questions that will inform the details we include in your agreement.

Why choose Open Access?

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If you have questions about publishing your article, don't hesitate to contact us directly at LFRI-production@journals.taylorandfrancis.com

We look forward to seeing your article published, and we are pleased to have you in our authorship community.

Kind regards,

Food Reviews International Production Team
Taylor & Francis Group

Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Your completed Author Publishing Agreement DOI - 10.1080/87559129.2025.2570469

1 message

LFRI-production@journals.taylorandfrancis.com <LFRI-production@journals.taylorandfrancis.com> Wed, Oct 1, 2025 at 6:31 PM
To: probo@unika.ac.id

Dear P Y Nugrahedi,

Your Author Publishing Agreement for "Moisture migration and its prevention in multi-domain bakery products: a review" has been completed.

If you need a copy of your agreement you can access this below.

ACCESS MY AGREEMENT

If you have questions about publishing your article, please don't hesitate to contact us directly at LFRI-production@journals.taylorandfrancis.com

Kind regards,

Food Reviews International Production Team
Taylor & Francis Group

Number 3099067.

Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Welcome to Taylor & Francis Production: Food Reviews International 2570469

1 message

WMS <LFRI-production@journals.taylorandfrancis.com> Thu, Oct 2, 2025 at 7:50 PM
To: probo@unika.ac.id

Article: Moisture migration and its prevention in multi-domain bakery products: a review

Journal: Food Reviews International LFRI

Article ID: LFRI (2570469)

Dear P Y Nugrahedi

We are delighted that you have chosen to publish your article in *Food Reviews International*.

We expect proofs will be ready for you to check on 06 October 2025. We will be sending proofs to you through our online proofing system. You will receive notification when your proofs are available and the link to access them from the email address: iproof@integra.co.in.

The DOI of your paper is: 10.1080/87559129.2025.2570469. Once your article has published online, it will be available at the following permanent link: https://doi.org/10.1080/87559129.2025.2570469.

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Best wishes,
Food Reviews International Production Team
Email: LFRI-production@journals.tandf.co.uk

Unika SOEGIJAPRANATA

Probo Y. Nugrahedi <probo@unika.ac.id>

Welcome to Taylor & Francis Production: Food Reviews International 2570469

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Moisture migration and its prevention in multi-domain bakery products: a review

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Classifications:	food processing/engineering < Food Science and technology, Food Science and technology, food chemistry < Food Science and technology

Moisture Migration and Its Prevention in Multi-domain Bakery Products: A Review

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Moisture migration and its prevention in multi-domain bakery products: a review

Multi-domain bakery products are susceptible to moisture migration that potentially poses risk of softening, chemical reactions, and microbial growth. Various models have been developed to elucidate the dynamic of moisture migration between the components. These models help assess the influence of factors such as the presence of an edible barrier, air gap, surrounding air, permeable packaging, and contact conditions, leading to enhanced strategies for mitigating moisture migration. This review aims to summarize the mechanisms and key factors of moisture migration, compare recent models, discuss the impact of moisture migration on product quality, and to evaluate different prevention methods and their applicability to multi-domain bakery products.

Keywords: moisture migration, multi-domain, bakery products, water activity, models

Introduction

Bakery products are considered fundamental staples widely consumed worldwide.[1] The global bakery products market size was valued at USD 480.23 billion in 2024 and it is projected to grow from USD 504.78 billion in 2025 to USD 731.69 billion by 2032, growing at a CAGR of 5.45% during the forecast period.[2] Another market research reported the market size reached USD 532.6 billion in 2024 and it is expected to reach USD 701.1 billion by 2033, exhibiting a growth rate CAGR of 3.1% during 2025-2033.[3] A diverse range of bakery goods includes breads, pastries, cookies, pies, tarts, and cakes.[4] Initially, bakery products consisted of a single component. Subsequently as they evolved, products began to incorporate two or more components with varying appearances, textures, tastes, and other characteristics, resulting in combinations that offer a diverse array of sensory experiences.[5, 6] These products fall under the category

Unlike other prevention methods, lowering storage temperatures can be implemented in conjunction with other prevention methods, as it indirectly influences moisture migration.[40] However, caution is required when selecting the storage temperature, as it may lead to quality changes in bakery products and affect the overall supply chain cost and complexity. Lowering the storage temperature can also have adverse effects on product quality, particularly in relation to accelerated bread staling.[69]

Thoughtfully combining different prevention methods may be the best approach to optimize effectiveness in slowing moisture migration with minimal impact on the quality of bakery products. For instance, a strategy that combines a thin edible barrier, a gradual increase in fat content, and a slight reduction in the a_w of wet components may have a lesser impact on product characteristics while offering comparable or even improved moisture barrier properties compared to applying a single prevention method. Nevertheless, a feasibility study should be performed thoroughly to optimize the shelf-life extension in accordance with sensorial acceptance, technical and manufacturing capability, and cost-effective deliberation.

Conclusion

Moisture migration occurs in every multi-domain bakery product with water activity disparity between components. This can lead to significant quality changes, such as softening, chemical and microbial transformations, and eventually decreasing product shelf life. Mechanisms contributing to migration include capillary action, liquid diffusion, and vapor diffusion, as influenced by a thermodynamic factor, product composition and structure, and external elements.

The moisture migration models for multi-domain bakery products can reveal the mechanisms by incorporating various factors, such as an edible barrier, air gap,

surrounding air and permeable packaging, as well as contact conditions. Moreover, various methods including product formulation modification, porosity reduction, edible barrier application, and storage temperature reduction, can be employed to reduce moisture migration in multi-domain bakery products. Among these, the application of an edible barrier extends shelf life at the most. However, a combination of the methods may be preferred to maintain product quality while optimizing shelf life.

Further studies are necessary to validate moisture migration models on different multi-domain bakery products, including the fillings and constructions. Further studies on the physical, chemical, and microbial quality attributes of multi-domain bakery products could also be performed.

Declaration of Interest

No conflict of interest to disclose.

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1082 Table 1. Moisture migration models for multi-domain bakery products

Type of Models	Conditions / Assumptions	Validated on	References
Model 1	• Model for a 2-component food system placed side-by-side with the origin x-axis at the interface • a_w equilibrium reached instantaneously • 2 different cases: Non-rate limiting wet component and Rate limiting wet component • Sorption isotherm uses Ferro-Fontan equation	Sponge-cake + agar gel & cheese filling. Result: The model is suitable for predicting moisture migration between the sponge cake and agar gel, sufficiently accurate in predicting moisture transfer; slightly underestimated the experimental data (cheese+sponge cake) near the interface	[38]

Type of Models	Conditions / Assumptions	Validated on	References
Model 2	• Adapt the 2-component food model by Guillard et al., [38] to consider the presence of an edible barrier at the interface • Model for a 3-component food system placed side-by-side • a_w equilibrium reached instantaneously • Non-rate limiting wet component, rate-limiting barrier, and dry component • The dry component is initially at a uniform concentration, and no moisture gradient exists at the end of the dry component • Sorption isotherm uses Ferro-Fontan equation	Sponge-cake + edible film (Acetylated Monoglycerides, dark chocolate, wheat gluten) + agar gel. Result: The model can predict the local moisture content of the three-component food system.	[41]

Type of Models	Conditions / Assumptions	Validated on	References
Model 3	• Modify the 2-component food model [38] to consider the presence of an air gap of varying thickness. • The model is composed of 3 finite cylindrical components placed in contact with each other • The steady-state regime for vapor diffusion in the air gap was reached instantaneously • a_w at the interface is reached instantaneously • Wet components are non-rate limiting • Sorption isotherm uses Ferro-Fontan equation	Sponge-cake + agar gel. Result: The simulated moisture profile of the sponge cake exhibited good agreement with the experimental data; a slight inaccuracy was observed at the agar gel near the interface.	[35]

Type of Models	Conditions / Assumptions	Validated on	References
Model 4	• Moisture migration model for a 2-component food system in permeable packaging based on Ficks and Henry's law • Assumed homogeneous and isotropic food with unidirectional water diffusion between components. • Assumed instantaneous moisture equilibrium between the surface of the biscuit and the surrounding • Assumed wet components have constant a_w and a_w at the interface of the dry and wet components were always in equilibrium • Assumed that all water vapor from outside is absorbed by the dry components. • Assumed the food components are in perfect contact and there is negligible external resistance to mass transference in the medium air • Assumed that the product quality is determined by the dry component and critical moisture content is low	Biscuit + pork & hawthorn sheet. Result: The model exhibited a good fit to the experimental results at time lower than 5 hours. However, at above 5 hours it slightly overestimated the moisture content of the biscuits.	[34]

Type of Models	Conditions / Assumptions	Validated on	References
Model 5	• Moisture migration model on a 2-component food system with imperfect contact conditions • The model is developed based on a porous media framework, with the chicken and bread considered as a porous medium • Assumed that all phases in the system (solid, liquid, and gas) are in continuum • Assumed that the vapor pressure at the interfaces reached equilibrium instantaneously • Any material deformation due to drying during storage are neglected • Effects of gravity are ignored • The ideal gas law applies to the gasses in the system • Developed pressures because of evaporation are assumed insignificant, or the system maintains atmospheric conditions	Bread + chicken. Result: The model was in a good agreement with experimental data. There were discrepancies in the time to reach equilibrium, equilibrium moisture content, and equilibrium a_w. It slightly underestimated the amount of water loss by the chicken and the gain by the bread	[5]

Type of Models	Conditions / Assumptions	Validated on	References
Model 6	• Moisture migration model for wet-dry component placed side-by-side • Model is made based on previous study [38] • Uses Finite Element Method (FEM) to solve the moisture migration • a_w equilibrium at the interface is reached instantaneously	Biscuit + hawthorn sheet & agar gel. Result: Satisfactory correlation between the model and experimental data. The simulated moisture content exhibited good agreement with the experimental results	[8]

Type of Models	Conditions / Assumptions	Validated on	References
Model 7	• Create a moisture migration model for 2 component food systems with different contact conditions based on Fick's second law • Full Contact, No Contact, Partial contact • Diffusion is unidirectional • a_w at the interface are reached instantaneously • Impermeable packaging conditions • The partial contact conditions are predicted using a combination of X_{full} and X_{non}	Cookie + agar gel. Result: The model accurately predicted the moisture content changes in diverse three contact conditions.	[14]

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Table 2. Potential transformations due to moisture migration in multi-domain bakery products

Changes Categories	Possible Changes
Physical Changes	Dry Component (Bakery Products): • Softening, loss of firmness, or sogginess of the dry component [15, 37, 43, 44] • Loss of crispness in low a_w bakery products [24, 48] • Swelling of particles within the products [27, 49] resulting in reduced porosity • Changes in density [38] due to weight redistribution and volume changes Wet Component (Filling): • Crystallization of sugars within fillings [33]
Chemical Changes	• Increase in lipid oxidation rate above monolayer moisture content [33] • Possible effects of non-enzymatic browning [33]
Microbiological Changes	• The increase in a_w above growth limit can promote microbial growth. The minimum a_w values for the growth of spoilage microorganisms[42, 55] are 0.60 – 0.70 for osmophilic yeasts, xerophilic molds, 0.80 – 0.90 for molds and yeasts, and 0.90 for bacteria

Table 3. Prevention of moisture migration towards the shelf life of multi-domain bakery products

No	Components/RH difference between components	Prevention method applied	Results/Shelf life extension	References
Low a_w Bakery Products (a_w<0.6)				

No	Components/RH difference between components	Prevention method applied	Results/Shelf life extension	References
a	Thin, Porous Dry Biscuit (a_w 0.11) - Agar Gel (a_w 0.99, 0.75, 0.7, 0.6, 0.5) & Concentrated Strawberry Jam (a_w 0.64)	1. Reduction in agar gel a_w by humectant addition (FRUCTOR) 2. Application of an edible film from a commercial blend of white beeswax and Acetic Acid Ester of Mono- & Diglycerides (Wax/ACETEM) between the dry and wet component	1. Shelf life[a]: a. 0.11-0.99 a_w System: 0.11 hours b. 0.11-0.75 a_w System: 2 hours c. 0.11-0.70 a_w System: 3 hours d. 0.11-0.64[b] a_w system: 4 hours e. 0.11-0.60 a_w system: 7 hours f. 0.11-0.50 a_w system: 43 hours 2. Shelf life[a]: a. 0.11-0.99 a_w system: 300 hours b. 0.11-0.75 a_w system: 320 hours c. 0.11-0.60 a_w system: 1010 hours	[29]

No	Components/RH difference between components	Prevention method applied	Results/Shelf life extension	References
b	Short dough sweet cookie (a_w 0.23) - Agar gel (a_w 0.999) & Concentrated strawberry jam (a_w 0.64)	1. Use of a lower a_w wet component (a_w 0.99 to 0.64) 2. Addition of fat in the cookie formulation (0.34, 0.47, 0.53 g fat / d.b.) 3. Application of a sprayed edible barrier (Commercial blend of white beeswax and Acetic Ester of Mono- and Diglycerides or Wax-ACETEM) on the surface of the cookie	1. Shelf life[c]: a. 0.23-0.99 a_w system (no fat, untreated): <1 day b. 0.23-0.64 a_w system (no fat, untreated): 6 days 2. Shelf life[c]: a. High-fat cookie (0.53 g fat / d.b.): 8 days 3. Shelf life[c]: a. Barrier treated cookie: 14 days	[61]
c	Dry Biscuit (a_w 0.18) - Agar gels (a_w 0.90)	Application of an Acetylated Monoglyceride film (TSED619) between the dry and wet component	Shelf life[d]: a. Control cookie: a few hours b. With edible film (316.1±14.5µm): > 3 days	[26]

No	Components/RH difference between components	Prevention method applied	Results/Shelf life extension	References
d	Dry Biscuit - Agar Gel (a_w 0.75)	1. Application of nine lipid-based edible barriers (white chocolate, milk chocolate, dark chocolate, white beeswax, two commercial blend of white beeswax and Acetic Acid Ester of Mono- and Diglycerides [ACETEM 1 & ACETEM 2], Acetylated Monopalmitine [AMP], two commercial fat barriers based on hydrogenated and fractionated vegetable fat (Barrier fat 1 & Barrier fat 2) with the thickness of ±300 µm between the dry and wet components. 2. Variations of film thickness for several barriers	1. Shelf life[a]: a. Control: <2 hours b. White chocolate (310 µm): 40 hours c. Milk chocolate (327 µm): 35 hours d. Dark chocolate (330 µm): 40 hours e. AMP (333 µm): 107 hours f. Wax/ACETEM 1 (278 µm): 101 hours g. Wax/ACETEM 2 (270 µm): 330 hours h. White beeswax (272 µm): 320 hours i. Barrier Fat 1 (275 µm): 42 hours j. Barrier Fat 2 (376 µm): 50 hours 2. Shelf life[a]: a. Milk chocolate (656 µm): 87 hours b. Wax/ACETEM: 2	[29]

No	Components/RH difference between components	Prevention method applied	Results/Shelf life extension	References
Intermediate to High a_w Bakery Products (a_w>0.6)				
e	Cannoli - Ricotta Based Filling	Use of a Zein based coating (1, 2, and 3 layers) to coat the inside of the cannoli, an antimicrobial compound in the filling,	Shelf life[e]: a. Control A (No coating and antimicrobial compound, pack 1 packaging): 1.65±0.501 days b. Treated A (pack 1 packaging): 3.29±0.293 days c. Control B (No coating and antimicrobial compound, pack 2 packagings): 1.48±0.256 days d. Treated B (pack 2 packaging): 4.82±0.401 days	[57]

No	Components/RH difference between components	Prevention method applied	Results/Shelf life extension	References
f	White Pan Bread (a_w 0.88) - Processed Cheese (a_w 0.92)	1. Bread structure modification by yeast content (1%, 3%, 6%) and proofing time 2. Adjustment in bread oil content (0%, 5%, 10%, 15%) 3. Increase in bread crumb crystallinity by resistant starch (0%, 5%, 10%) addition to replace flour 4. Increase in bread crumb intermolecular interaction by gluten (0%, 5%, 10%) addition	1. An increase in bulk density (porosity reduction) reduces moisture sorption by the bread 2. An increase in oil content significantly reduce added moisture and total moisture absorbed 3. The highest resistant starch content (20%) primarily shows significant moisture sorption reduction, up to half the no-added-starch sample (0%) 4. An increase in gluten content promotes moisture migration into the bread	[45]

No	Components/RH difference between components	Prevention method applied	Results/Shelf life extension	References
g	Sponge Cake (a_w 0.85) - Agar gel (a_w 0.99)	1. Reduction in sponge cake porosity (67% and 52%) by reduced beating time 2. Addition of fat in the sponge cake (0 and 0.30 g/g d.b.)	1. Shelf life[f]: a. 67% porosity sponge cake: 2.2 days b. 52% porosity sponge cake: 4.7 days 2. Shelf life[f]: a. 0 g/g d.b. fat content sponge cake (67% porosity): 2.2 days b. 0.30 g/g d.b. fat content sponge cake (65% porosity): 4.2 days	[60]

No	Components/RH difference between components	Prevention method applied	Results/Shelf life extension	References
h	Sponge cake (a_w 0.84) - Agar gel (a_w 0.99)	1. Application of two Acetylated Monoglyceride films (ACETEM 50.00 & TSED619) between the dry and wet component 2. Modification of storage temperatures (5°C & 35°C) 3. The combined effect of edible barrier and storage temperature 4. Effect of fluctuating temperature (5°C-20°C-35°C)	1. Shelf life (20°C)[g]: a. No film: 6 hours b. ACETEM film: 6 days c. TSED619 film: 9 days 2. Shelf life (No film)[g]: a. 5°C storage: 1 day b. 20°C storage: 6 hours 3. Shelf life[g]: a. ACETEM at 5°C: >15 days b. TSED619 at 5°C: >15 days c. ACETEM at 35°C: 1.5 day d. TSED619 at 35°C: Not measured[h] 4. Shelf life[g]: a. No film: 10 hours b. ACETEM film: 4.3 days c. TSED619 film: 5.5 days	[40]

[a]Time to reach critical a_w of 0.4 (20°C) based on sensory quality

[b]Concentrated jam wet component, other variable uses agar gels as the wet component

[c]Time to reach 5g/100g w.b. critical moisture content based on texture

[d]Time to reach 10% w.b. critical moisture content based on texture

[e]Shelf life based on microbial quality threshold

[f]Time to reach critical a_w of 0.92 based on texture, results are simulated based on models with input parameters from experimental results

[g]Time to reach critical a_w of 0.87 or critical moisture content of 30g/100g w.b. based on yeast growth limit

[h]Due to the low melting point of TSED619 (30°C)

Table 4. Strength and weakness of moisture migration prevention method in multi-domain bakery products

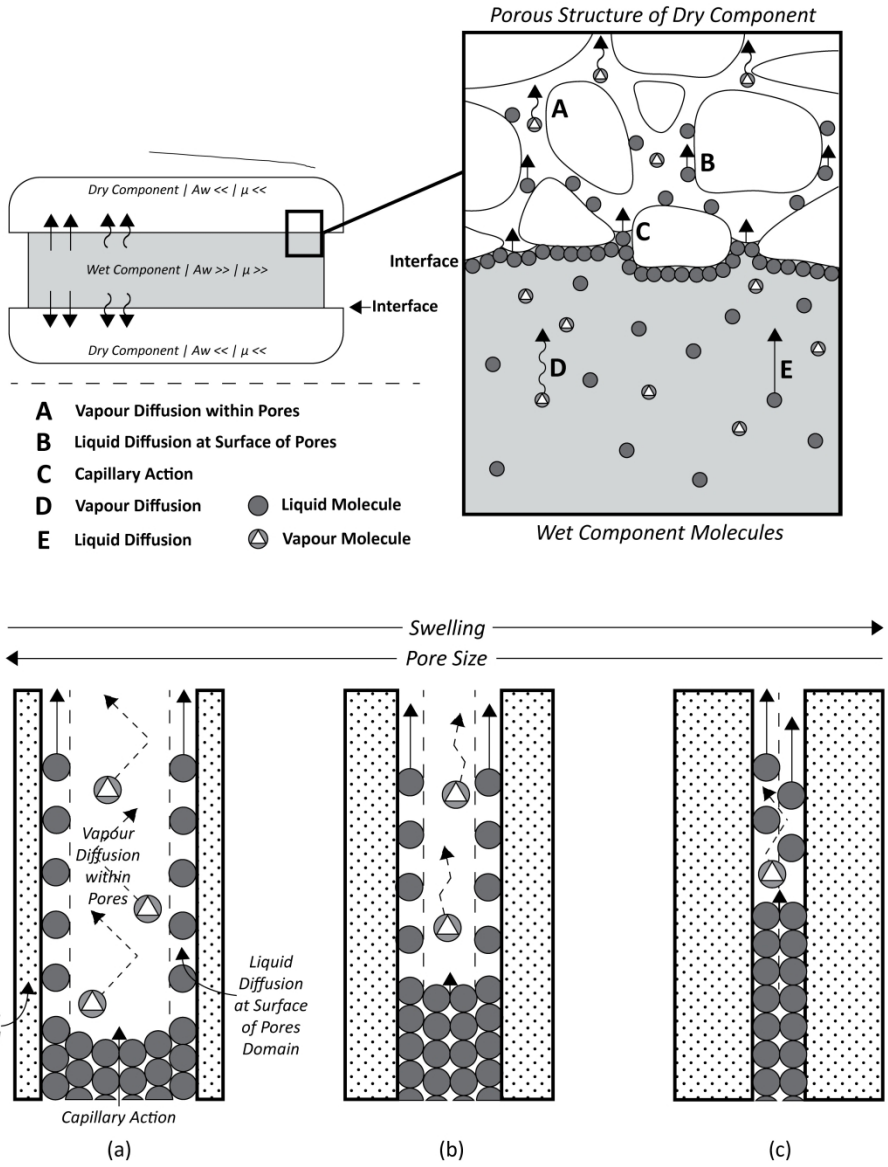
Prevention Method	Strength	Weakness
Reduction in a_w difference (addition of humectants in the wet component)	Maintain the soft texture of the wet component [33] and reduce the effective moisture diffusivity [29]	• Humectants can cause unwanted flavor changes [33] • Humectants can negatively impact textural properties [42] • Limited by the toxicity of the a_w lowering substance[33] • Possible effect on chemical reactions[33] • May cause the need for complete reformulation to reach the desired a_w reduction[61]

Prevention Method	Strength	Weakness
Increase in fat content	Fat globules hinder moisture migration and reduce the effective moisture diffusivity[61]	• Significant addition of fat is needed to obtain a significant extension in shelf life[61] • Technological and sensory limitations, as high-fat content, can cause changes in texture (such as loss in crispiness and sandy texture in cookies)[61] • Can negatively impact nutritional value if used at large amount [61]
Reduction in porosity	• Can be performed relatively easily without significant changes to the formulation/processing method	• Will result in a denser product[45], which may impact consumer's sensory acceptance

Prevention Method	Strength	Weakness
Application of an edible barrier	• Significantly higher extension in shelf life than other prevention methods (i.e. reduction in a_w difference and increase in fat content) [29, 61] • May have a lower impact on nutritional value than other prevention methods, i.e. fat addition [61] • Can slow microbial growth by addition of natural antimicrobial in the barrier [58] • Can improve components adherence [15]	• May have an impact on consumers sensory perception, especially in thick barriers [61] • A fat-based edible barrier may impart a greasy texture [15, 61] • May cause separation from components that negatively affect consumer's sensory experience [15] • Fluctuation in temperature may affect barrier efficiency and/or permanently damage the barrier [40] • Defects on the barrier's structure can significantly reduce the barrier's effectiveness [29]
Reduction in storage temperature	• Can be used in combination with other prevention methods	• May cause faster deterioration of bakery product's quality[35]

Figure caption

Figure 1. Mechanism of moisture migration in multi domain bakery products



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