



Research Article

Process Development and Quality Evaluation of a Ready-to-Serve Khichuri Mix Using Hot Air Dehydration

Md. Mobarak Hossain¹, Mst. Arefa Yeasmin²✉, Istihuk Ahmad Niloy¹, Md. Moshir Rahman Munna¹, Md. Anisur Rahman Mazumder¹ and Abdullah Iqbal¹¹Department of Food Engineering and Technology, Bangladesh Agricultural University, Mymensingh, Bangladesh²Department of Food Engineering, Gopalganj Science and Technology University, Gopalganj, Bangladesh

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ABSTRACT

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Correspondence

Mst. Arefa Yeasmin

✉: arefayeasmin@gstu.edu.bd

The pre-cooked, ready-to-serve khichuri mix offers a convenient, nutritious meal option that requires minimal preparation. This study evaluated its chemical composition and drying characteristics under different drying temperatures. Proximate composition, moisture behavior, and thin-layer drying kinetics were analyzed, and drying data were fitted to the Newton–Lewis, Page, and Henderson–Pabis models, showing strong agreement ($R^2 = 0.964–0.993$). Increasing drying temperature significantly reduced drying time and improved dehydration efficiency. Samples dried at 95°C exhibited the lowest moisture content ($17.29 \pm 0.44\%$) and lower protein ($27.04 \pm 0.38\%$) and higher carbohydrate ($50.65 \pm 0.42\%$) contents compared to those dried at 85°C and 70°C. The activation energy for water diffusion was 6.649 kcal/g-mole. Lipid oxidation indicators, including peroxide and acid values, varied with temperature and were higher in dried samples. Sensory evaluation revealed significant differences ($p < 0.05$) among samples, with drying temperature influencing color, flavor, texture, and overall acceptability. These findings demonstrate the feasibility of producing a shelf-stable khichuri mix that retains quality for convenient food applications.



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Introduction

Processed foods are classified as fresh or processed, with processed foods further divided into ready-to-eat (RTE) and ready-to-cook (RTC) types. The increasing demand for convenient, nutritious, and easy-to-prepare meals has driven consumer preference toward RTE and RTC products, which provide variety, improved flavor, and significant time savings (Malik et al., 2018; Alvarez et al., 2018). Khichuri, a traditional Indian dish prepared from green gram (*Vigna radiata*) and rice in nearly equal proportions, represents a nutritionally balanced meal. It supplies carbohydrates primarily from rice, along with proteins and resistant starch from pulses, making it a wholesome single-serving food (Negi et al., 2021; Rahangdale et al., 2015). Resistant starch additionally contributes to gut health and glycemic control,

enhancing the functional value of khichuri beyond basic nutrition (Negi et al., 2021).

Recent studies have explored fortifying instant khichuri to address micronutrient deficiencies, particularly anemia in children and adolescents. Rajeswari et al. (2023) developed a calcium and iron-enriched instant khichuri by incorporating multiple millets, thereby improving its nutritional profile and potential health benefits. Precooking, a critical thermal step in RTC khichuri production, influences the digestibility and bioavailability of macronutrients, including proteins and carbohydrates (Rehman & Shah, 2005). This process facilitates partial gelatinization and protein denaturation, enhancing nutrient accessibility and reducing antinutritional factors. Optimization of thermal parameters is essential to preserve both nutrient retention and sensory quality.

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Most research on instant grain products has focused on hot-air drying techniques and on pretreatment methods that affect product quality (Wang et al., 2022). These factors significantly influence dehydration kinetics, rehydration capacity, texture, and overall acceptability of the final product. However, comprehensive studies on the drying kinetics, physicochemical characteristics, and quality attributes of ready-to-serve khichuri mixes under varying drying conditions remain limited. Furthermore, few studies have applied thin-layer drying models with statistical validation to multi-ingredient RTC products, and information on activation energy for water diffusion in such matrices is scarce.

Therefore, this study investigates the development of a ready-to-serve khichuri mix using optimized precooking combined with mechanical dehydration. Thin-layer drying models with statistical validation were applied to describe the drying behavior, and activation energy for moisture diffusion was determined. The effects of drying temperature on chemical composition, lipid oxidation, and sensory attributes were also evaluated to assess product quality and consumer acceptability.

Materials and methods

Materials

Raw materials, such as rice, mung beans, turmeric powder, red pepper powder, cumin powder, coriander powder, ginger, garlic, onion, salt, cardamom, cloves, cinnamon, bay leaf, and oil, were purchased from the local market. All the purchased ingredients were assessed for safety standards. The names of the products, batch numbers, physicochemical composition, information on food allergens, sensory properties, microbial safety, and shelf life were evaluated. High-density polyethylene and low-density polyethylene were used as packaging materials to store the ingredients.

Experimental design

The rice and lentils were rinsed separately under running water until the water ran clear. This helped to remove excess starch and impurities. Then, the water was drained from the rice and lentils. The onions were chopped into small pieces. Garlic and ginger were used for further preparation.

Table 1: Basic Formulation of khichuri mix (per 100g total product).

Ingredient	Amount (g/100g)
Rice	23.60
Mung bean	7.80
Turmeric powder	0.04
Red pepper powder	0.04
Cumin powder	0.04
Coriander powder	0.04
Ginger paste	1.16
Onion	1.16
Garlic paste	1.15
Salt	1.00
Cardamom	2 pcs
Cloves	3 pcs
Cinnamon	3 pcs
Bay leaf	2 pcs
Oil	2.8 ml
Water	63.97

Preparation and cooking of khichuri

First, rice and mung beans (lentils) were fried at medium-high temperature. In a large cooking container, the oil was heated to around 140°C. Whole spices, such as cumin seeds, cloves, and cardamom pods, were added. It was sautéed for a minute until fragrant. The chopped onion was then added and sautéed for a few minutes until it softened. Fried rice and lentils were added and mixed well with the spices.

Ground spices, including turmeric, coriander, and cumin, were added. All raw materials were mixed to coat the grains evenly with spices.

Water was added to the container according to the formulation. The exact amount of liquid may vary based on the type of rice used and desired consistency. The mix was seasoned with salt, stirred well, and boiled at 120°C. After boiling, the heat was reduced to low (around 80°C), the pot was covered, and it was simmered. Occasionally, the mixture was stirred to

prevent it from sticking. The mixture was simmered until the rice and lentils were cooked and had reached a

masala was sprinkled over the khichuri, which was then stirred.

porridge-like consistency. This usually took approximately 20-30 min. Once cooked, the garam (a)

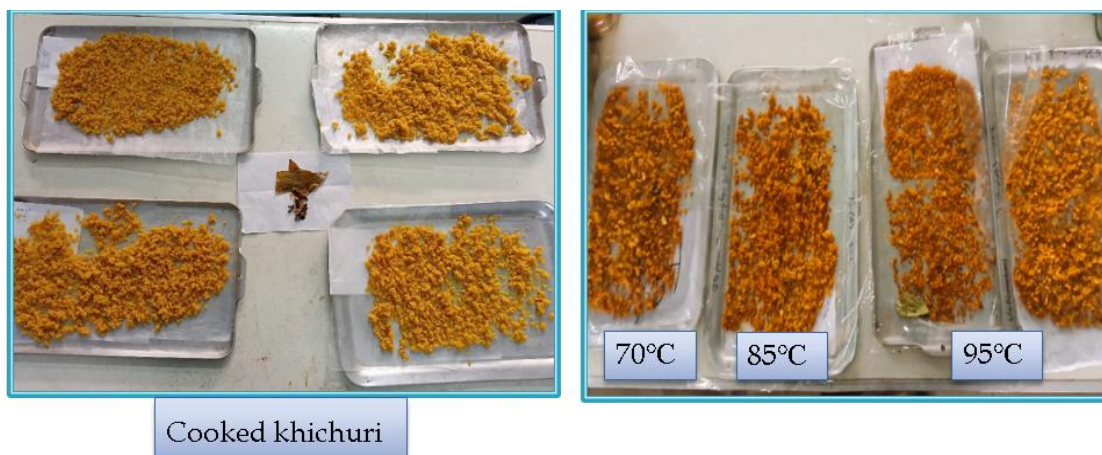


Fig. 1: (a) Cooked khichuri (S_1), (b) khichuri dried at 70°C (S_4), 85°C (S_3), and 95°C (S_2).

Ready-to-serve khichuri preparation

A cabinet dryer (Model No.: 1816; Modern Laboratory Equipment Co., Inc., New York, U.S.A.) was used to dehydrate khichuri. The dryer has a chamber with trays for product placement, where a fan circulates air through a heater before it passes over the trays. The air velocity was maintained at 0.6 m/s, as measured with an anemometer. The initial moisture content of the treated samples was determined before drying. Khichuri samples with a uniform thickness of 2 mm were placed on the trays and dried under constant air velocity.

For ready-to-serve khichuri preparation, the cooked product was divided into four portions. One portion was retained as cooked control, and the other three were dried at 70, 85, and 95°C, respectively. The dehydration process involved repeated drying and cooling cycles: samples were dried for 25 min, then placed at -18°C for 5 min, and the cycle was repeated four times to achieve the desired product characteristics. Freezing may help faster dehydration (Ando et al., 2013), and may also promote the formation of porous structures in the product, which may facilitate water penetration and thereby enhance rehydration capacity (Harnkarnsujarit et al., 2016; Grzegory et al., 2013). The final dried samples were packaged in PET containers and sealed for storage and subsequent use as ready-to-serve khichuri.

Analysis of prepared khichuri

Proximate composition

Khichuri samples were analyzed for moisture, protein, ash, fiber, and fat content using the AOAC (2005) methodology. Carbohydrate content was calculated by difference, i.e., by subtracting the sum of the percentages of protein, fat, ash, and moisture from 100, following Pearson (1970).

$$\text{Total carbohydrate} = 100 - (\text{moisture} + \text{ash} + \text{protein} + \text{fat}) \dots \dots \dots (i)$$

The energy value was calculated by multiplying each fraction of protein, fat, and carbohydrate by its corresponding physiological energy value and summing the results (Farzana et al., 2017) as follows:

$$\text{Energy (kcal/ 100 g)} = (4 \times \text{Protein}) + (9 \times \text{Fat}) + (4 \times \text{Carbohydrate}) \dots \dots \dots (ii)$$

Lipid oxidation

Lipid oxidation of ready-to-serve khichuri samples during storage was evaluated by determining peroxide value (PV) and free fatty acid (FFA) content. Peroxide value was measured to assess the formation of primary oxidation products, while free fatty acid content was determined to evaluate the extent of hydrolytic rancidity in the lipid fraction. Peroxide value was determined according to AOAC Official Method 965.33 by iodometric titration and expressed as milliequivalents of peroxide per kilogram of fat. Free fatty acid content was determined according to AOAC

Official Method 940.28 using standard alkali titration, and the results were expressed as a percentage of oleic acid. All analyses were carried out in triplicate, and the mean values were reported. Peroxide value and free fatty acid content were used as indicators of lipid oxidation and quality deterioration in the ready-to-serve khichuri samples during storage (AOAC, 2023).

Rehydration (reconstitution) of processed instant khichuri

Rehydration involves restoring dried products to their original condition by soaking them in water. In this procedure, 2 g of instant khichuri sample was placed in a 500 mL beaker containing 150 mL of water and left to soak for 20 min. Subsequently, the samples were transferred to another beaker containing 150 mL of boiling water at 100 °C. The time required for the water to resume boiling after immersion was recorded. After boiling, the liquid was drained, and the solids were transferred to a 10-cm-diameter Buchner funnel fitted with filter paper. Excess water was removed by applying gentle suction for a few seconds. Finally, the rehydrated samples were removed from the funnel and weighed individually. The following relationships were found:

$$\text{Rehydration ratio} = \frac{\text{Weight of rehydrated instant khichuri}}{\text{Weight of dehydrated instant khichuri}} \quad \dots \dots (iii)$$

$$\text{Coefficient of reconstitution} = \frac{\text{Rehydration ratio}}{\text{Dehydration ratio}} \quad \dots \dots \dots (iv)$$

Sensory evaluation of instant khichuri

Ready-to-serve khichuri samples were evaluated for color, texture, taste, aroma, and overall acceptability by a semi-trained panel of 15 members comprising academic staff from the Department of Food Engineering and Technology at Bangladesh Agricultural University and postgraduate students with sensory

evaluation experience. The panel included both males and females aged 22 to 40 years. Sensory analysis was carried out using a 9-point hedonic scale, where 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Neither like nor dislike, 6 = Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely (Hooda, S. & Jood, S., 2005). Before evaluation, ready-to-serve khichuri samples were prepared according to the standard reconstitution procedure and served warm (approximately 55°C) in identical white disposable bowls. Each sample was coded with randomly generated three-digit numbers to prevent bias. Equal portions were provided to each panelist, along with water for palate cleansing between samples. Panelists received instructions on using the hedonic scale and evaluated the samples independently under well-lit, odour-free, and quiet conditions to ensure reliable sensory assessment. The collected data were used to assess overall acceptability and preferences among the different khichuri formulations.

Statistical analysis

All physical and chemical analyses were conducted in triplicate (n=3) and expressed as mean ± standard deviation, while 15 panelists performed sensory evaluation. Data were analyzed using one-way ANOVA (GLM procedure) in SAS version 9.4, with sample (S₁–S₄) as the fixed factor. Significant differences (p < 0.05) among means were determined using Tukey's HSD test.

Results and discussions

Effect of temperature on the Composition of the formulated khichuri Sample

Table 2 shows the chemical compositions of the cooked and prepared instant products.

Table 2: Proximate composition and oxidative stability of cooked and instant khichuri.

Parameter	Sample			
	S ₁	S ₂	S ₃	S ₄
Moisture (%)	60.43 ± 0.11 ^a	17.29 ± 0.44 ^d	19 ± 0.93 ^c	22.30 ± 0.56 ^b
Protein (%)	16.19 ± 0.14 ^d	27.04 ± 0.38 ^c	28.15 ± 0.26 ^b	29.07 ± 0.10 ^a
Fat (%)	1.58 ± 0.14 ^a	152 ± 0.14 ^a	1.54 ± 0.10 ^a	1.56 ± 0.09 ^a
Ash (%)	1.55 ± 0.02 ^c	3.50 ± 0.04 ^a	3.44 ± 0.02 ^{ab}	3.33 ± 0.15 ^b
Carbohydrates (%)	20.25 ± 0.29 ^d	50.65 ± 0.42 ^a	47.87 ± 0.82 ^b	43.74 ± 0.99 ^c
Gross Energy (Kcal/100g)	160.3 ± 1.1 ^d	326.6 ± 2.3 ^a	316.1 ± 1.9 ^b	309.7 ± 2.7 ^c
Peroxide Value (meq/kg)	1.80±0.08 ^c	3.99±0.14 ^a	2.49±0.09 ^b	2.00±0.08 ^c
Free Fatty Acid (%)	0.40±0.04 ^c	0.51±0.03 ^a	0.49±0.03 ^{ab}	0.45±0.03 ^{bc}

S₁= Cooked khichuri, S₂=Khichuri processed at 95°C, S₃= Khichuri processed at 85°C, S₄ = Khichuri processed at 70°C. Values are presented as mean ± standard deviation (n = 3). Within each row, means with different superscript letters differ significantly (p < 0.05). Carbohydrate content was calculated by difference [100 – (moisture + protein + fat + ash)], while gross energy (kcal/100 g) was calculated using standard

Atwater factors based on protein, fat, and carbohydrate contents. Both parameters were calculated separately for each replicate; thus, their standard deviations represent variability among the calculated replicate values rather than error-propagated estimates from the directly measured components.

Table 2 clearly indicates that temperature directly affected the proximate composition of the products. Moisture content varied significantly among the samples ($p < 0.05$). Cooked khichuri demonstrated the highest moisture content (~60%) among all others. Among the processed samples, S_4 exhibited the highest moisture, followed by S_3 and S_2 . Sample S_2 , processed at the highest temperature, had the lowest moisture content ($17.29 \pm 0.44\%$). Tukey's HSD test showed that all samples differed significantly. Higher drying temperature increases the vapor pressure gradient between the product surface and surrounding air while also enhancing moisture diffusivity within the food matrix, together accelerating the rate of water evaporation. Consequently, at 95°C (S_2), more water was removed in the same drying time than at 70°C (S_4), resulting in S_2 having the lowest final moisture content. As drying temperature increased, both protein and fat content decreased significantly. Protein content varied significantly among the samples ($p < 0.05$). Sample S_4 exhibited the highest protein content ($29.07 \pm 0.10\%$), followed by S_3 ($28.15 \pm 0.26\%$) and S_2 ($27.04 \pm 0.38\%$), whereas S_1 showed significantly lower protein content ($16.19 \pm 0.14\%$). Protein loss may result from denaturation or solubility changes during drying. Another possible cause is the release of amino acids from proteins after denaturation, which could react with other compounds, such as sugars, to produce melanoidins via the Maillard reaction. Tukey's HSD test indicated significant differences among all samples. The fat content ranged from 1.52% to 1.58%. One-way ANOVA indicated no significant difference among the samples ($p > 0.05$). S_1 shows the highest mean fat content, while S_2 is slightly lower. Fat reduction may be due to increased lipid oxidation as drying temperature increased. Both ash and carbohydrate content increased with temperature, likely because moisture content decreased. Sample S_2 presented the highest ash content ($3.50 \pm 0.04\%$), followed by S_3 and S_4 , whereas S_1 showed significantly lower ash content ($1.55 \pm 0.02\%$). Tukey's HSD test revealed significant differences among the samples. Carbohydrate content ranged from $20.25 \pm 0.29\%$ to $50.65 \pm 0.42\%$. Sample S_2 exhibited the highest carbohydrate content, followed by S_3 and S_4 , whereas S_1 showed significantly lower carbohydrate content according to Tukey's HSD test. The observed increase in protein and ash content, alongside decreasing moisture, is largely attributable to a concentration effect: as moisture was progressively removed during drying, the relative proportion of the

remaining solid components (protein, ash, carbohydrate) increased on a percentage basis, even though their absolute amounts remained relatively stable. These results agree with those reported by Alakali et al. (2015).

Temperature plays a significant role in lipid oxidation, a chemical reaction that degrades lipids (fats and oils) in food and other materials. Free fatty acid content often indicates fat hydrolysis. Table 2 shows statistically significant differences among the samples for both peroxide and free fatty acid values ($p < 0.05$). The mean peroxide values ranged from 1.80 to 3.99 meq/kg, whereas the free fatty acid values ranged from 0.40 to 0.51%. The peroxide value and free fatty acid value for the S_2 sample exhibit significantly higher lipid oxidation ($PV = 3.99 \pm 0.14$ meq/kg, $FFA = 0.51 \pm 0.03$), followed by S_3 ($PV = 2.49 \pm 0.09$ meq/kg, $FFA = 0.49 \pm 0.03$), while S_1 and S_4 show similar and comparatively lower oxidation levels. These data suggest that fat oxidation increases with increasing temperature. López et al. (1997) found that in hazelnut drying, temperatures higher than 50°C favor an increase in the rate of lipid oxidation in unshelled hazelnuts, which means increased drying temperatures led to higher peroxide values and free fatty acid content, indicating greater lipid degradation, as found by Kashani et al. (2023) in their study with dried nuts.

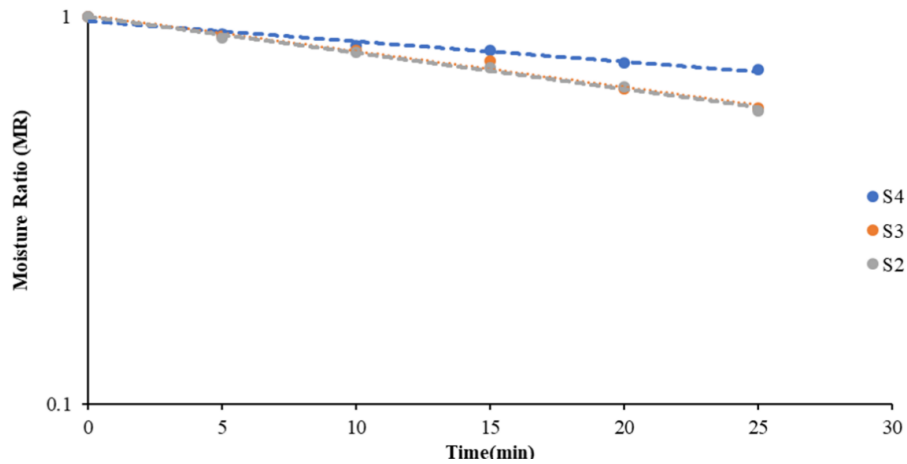
Effect of drying temperature on the moisture ratio of formulated khichuri

To analyze the effect of temperature on drying time, two mm-thick ready-to-serve khichuri were dried in a cabinet dryer at three air dry-bulb temperatures: 95°C , 85°C , and 70°C . The experimental data were evaluated using the equation given by Islam (1980) and Aral and Bese (2016). Moisture ratio versus drying time was plotted on semi-log coordinates, and regression lines were drawn (Figure 2). Consequently, the following regression equations were developed.

$$MR = 0.9993 \exp^{-0.022t} \text{ (for } 95^\circ\text{C; } t = \text{time, min) (1)}$$

$$MR = 1.0078 \exp^{-0.021t} \text{ (for } 85^\circ\text{C; } t = \text{time, min) (2)}$$

$$MR = 0.9728 \exp^{-0.012t} \text{ (for } 70^\circ\text{C; } t = \text{time, min) (3)}$$



S₂=Khichuri processed at 95°C, S₃= Khichuri processed at 85°C, S₄ = Khichuri processed at 70°C

Fig. 2: Effect of drying temperature on the moisture ratio of 2mm ready-to-serve khichuri

Figure 2 shows that as the temperature increased, the drying rate constant also increased. The drying rate constants for khichuri dried at 95°C, 85°C, and 70°C were 0.022, 0.021, and 0.012 min⁻¹, respectively. Increasing the drying temperature increased the drying rate because the higher water vapor pressure promoted greater pore opening in the samples. These findings align with those of Ndukwu (2009), who studied the effects of various drying parameters and conditions on cocoa beans at three temperature levels (55, 70, and 81°C) and found that the drying rate increased with increasing temperature. Additionally, Song et al. (2019) found that higher drying temperatures increased the

drying rate in their experiment on drying lotus pollen at 40, 50, 60, and 70 °C.

Model fittings

Nonlinear regression analysis was performed using Microsoft Excel 2013. The parametric values of Newton's model (Westerman et al., 1973), modified Page's model (Yaldiz et al., 2001), and Henderson and Pabis's model (Yagcioglu et al., 1999) were determined along with the corresponding correlation coefficients (R²).

Table 3: Results of the fitting statistics of various thin-layer models.

Sample	Newton/Lewis model		Page model			Henderson and Pabis' model		
	k	R ²	k	n	R ²	k	a	R ²
S ₄	0.014	0.967	0.083	0.167	0.967	0.011	0.952	0.964
S ₃	0.020	0.983	0.141	0.148	0.983	0.020	0.960	0.984
S ₂	0.021	0.993	0.146	0.146	0.993	0.021	0.996	0.993

k= drying rate constant; a, n = model parameters; Where, S₂=khichuri processed at 95°C, S₃= khichuri processed at 85°C, S₄ = khichuri processed at 70°C

Table 3 demonstrates that the drying rate constant increases with increasing temperature. At 70°C, the drying rate constants were lowest, and at 95°C, they were highest, for each model. The drying process proceeded faster when the drying rate was higher. This table also demonstrates that constants n and a decrease as the temperature rises, which is consistent with the results of Macedo et. al. (2020), who attempted model fitting for three distinct temperatures (40, 60, and 80°C) in dried banana products and obtained the lowest drying rate constant value at 40°C and the highest drying rate constant at 80°C in each

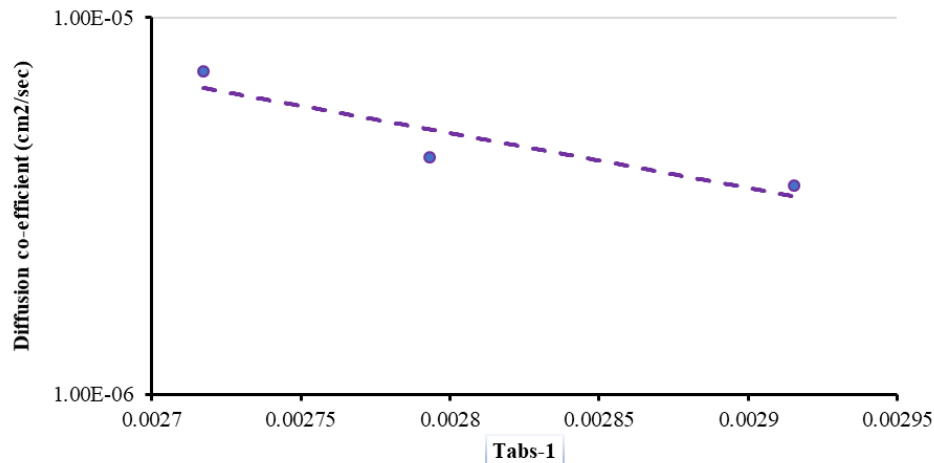
model. These models fit well because the regression coefficients range from 0.964 to 0.993.

Temperature dependence of diffusion coefficient and evaluation of activation energy

From the drying rate constants obtained from the relevant semi-theoretical drying equations for ready-to-serve khichuri dried at 95, 85, and 70°C (Equations 1, 2, and 3), diffusion coefficients were determined. To show the temperature dependence of diffusion coefficients as per the Arrhenius equation, diffusion coefficients were plotted versus inverse absolute temperature on

semi-log coordinates and regression lines (Figure 3), the developed equations are as follows:

$$D_{\theta} = 0.0578 \exp \frac{3346}{T_{abs}} \quad (4)$$



S_1 = Cooked khichuri, S_2 =Khichuri processed at 95°C, S_3 = Khichuri processed at 85°C, S_4 = Khichuri processed at 70°C.

Fig. 3: Effect of temperature on the diffusion coefficient of 2mm ready-to-serve khichuri

Equation 4 was sufficient to calculate the activation energy for the 2-mm-thick samples, which was 6.649 kcal/g-mole for ready-to-serve khichuri. Differences in activation energy may result from variations in product characteristics and process parameters, such as drying temperature. Islam (1980) stated that variations in activation energies may be due to changes in temperature, physical state, enzyme activity, and other factors.

Effect of rehydration

The rehydration ratio indicates how much dried food absorbs water and returns to its original state. A higher

rehydration ratio indicates higher quality, as the product retains more of its structure, porosity, and composition during drying. Table 4 shows that the S_3 sample (3.43) had a better rehydration ratio than the S_4 sample (3.15) but a lower one than the S_2 sample (3.49). Therefore, the S_2 sample was chosen for further use. These findings align with those of Srikanth et al. (2019), who showed that the rehydration ratio increased with drying temperature, reaching a maximum at 70°C and being lower for the sample dried at 40°C.

Table 4: Rehydration properties of ready-to-serve khichuri.

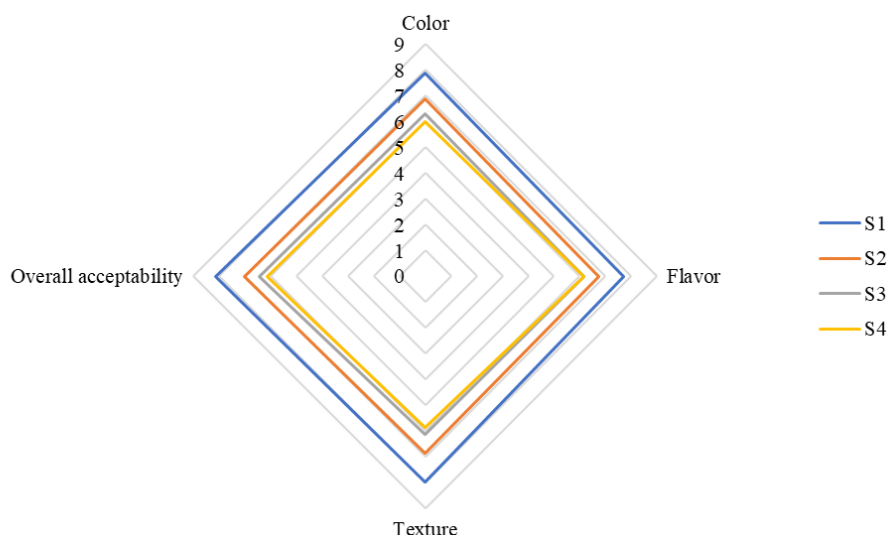
Sample	Rehydration Time(min)	Regained Weight (g)*	Rehydration properties		Texture of rehydrated khichuri
			Rehydration ratio	Rehydration rate (g of water per h)	
S_2	0	2	-	-	-
	5	5.10	2.55	12.40	Hard
	10	5.30	3.15	4.80	Moderately hard
	15	6.85	3.43	2.20	Moderately soft
	20**	6.97	3.49	0.48	Optimum
S_3	0	2	-	-	-
	5	4.50	2.25	10.20	Hard
	10	5.10	2.55	7.20	Moderately hard
	15	5.30	3.15	4.80	Moderately soft
	20**	6.85	3.43	2.20	Optimum
S_4	0	2	-	-	-
	5	4.15	2.075	8.60	Hard
	10	4.70	2.35	6.60	Moderately hard
	15	5.10	2.55	4.80	Moderately hard
	20**	5.30	3.15	2.40	Moderately soft

*Weight of dry sample 2 g, **selected for experimental studies due to optimal texture and rehydration properties, S_2 =Khichuri processed at 95°C, S_3 = Khichuri processed at 85°C, S_4 = Khichuri processed at 70°C

Sensory Evaluation of the Ready-to-Serve Khichuri

Sensory evaluation measures the reaction to stimuli resulting from consuming a food or food product (Meilgaard et al., 2014). The mean scores for color,

flavor, taste, texture, and overall acceptability of ready-to-serve khichuri are presented in Figure 4.



S₁= Cooked khichuri, S₂=Khichuri processed at 95°C, S₃= Khichuri processed at 85°C, S₄ = Khichuri processed at 70°C.

Fig. 4: Sensory evaluation of the ready-to-serve khichuri.

One-way ANOVA revealed significant differences among the samples in color, flavor, taste, and overall acceptability. This suggests the samples did not have comparable sensory qualities, with the largest difference between S₁ and S₂. There was no noticeable color variation between S₃ and S₄. Regarding flavor, S₁ received the highest score (7.71), while S₄ received the lowest score (6.14), reflecting the panelists' preferences. For texture, S₁ again received the highest rating (8), while S₃ and S₄ showed no significant differences. Both S₃ and S₄ received a score of 7, indicating no statistically significant difference. However, S₁ (8.14) differed substantially from S₂ (7), suggesting that S₁ was more widely accepted.

Conclusion

This study at Bangladesh Agricultural University investigated the drying kinetics, chemical composition, fat oxidation, presoaking effects, and sensory attributes of ready-to-serve khichuri dried at 70, 85, and 95°C. Results showed that higher drying temperatures reduced drying time and increased the drying rate constant. Drying models fit well ($R^2 = 0.964$ to 0.993), and the activation energy was 6.649 kcal/g-mole for 2 mm samples. Nutritional analysis indicated that drying at 95°C yielded the highest protein, carbohydrate, and ash contents, while moisture content was lowest. Fat oxidation increased with temperature, as evidenced by rising peroxide and acid values. The rehydration ratio

increased with temperature, whereas the rehydration rate decreased. Sensory evaluation revealed significant differences in flavor, texture, and overall acceptability, with sample S₁ receiving the highest ratings. Considering drying efficiency, nutritional quality, fat oxidation, rehydration characteristics, and sensory acceptability, the 95°C treatment (S₂) was identified as the overall optimum among the dried samples. Although S₁ was most preferred sensorially, it represented the cooked control and did not provide the dehydration and ready-to-serve characteristics targeted by this study.

Nonetheless, this study has certain limitations. The study did not independently monitor relative humidity within the drying chamber, and it assessed quality parameters only immediately after drying, without evaluating storage-related degradation such as rising peroxide and acid values. Consequently, the product's long-term stability remains unknown. Future studies should incorporate humidity monitoring, extended storage trials under varying packaging and environmental conditions, and evaluations using both traditional and high-yielding rice varieties.

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Author Contributions

Md. Mobarak Hossain: Writing – original draft, Methodology, Formal analysis, Data curation, Investigation, Visualization. Mst. Arefa Yeasmin: Writing – review & editing, Conceptualization, Supervision, Methodology, Validation. Istihuk Ahmad Niloy: Software, Formal analysis, Methodology, Visualization. Md. Moshir Rahman Munna: Investigation, Data curation, Visualization. Md. Anisur Rahman Mazumder: Writing – review & editing, Validation, Supervision. Abdullah Iqbal: Writing – review & editing, Validation.

References

- Alakali, J.S., Kucha, C.T. and Rabiou, I.A. 2015. Effect of drying temperature on the nutritional quality of *Moringa oleifera* leaves. *African Journal of Food Science*, 9: 395-399.
- Alvarez, M.V., Ponce, A.G. and Moreira, M.R. 2018. Influence of polysaccharide-based edible coatings as carriers of prebiotic fibers on quality attributes of ready-to-eat fresh blueberries. *Journal of the Science of Food and Agriculture*, 98: 2587-2597.
- Ando Y, Mizutani K, Wakatsuki N. 2013. Effect of blanching and freeze-thaw treatment on the drying rate and electrical impedance characteristics of carrots. *International Proceedings of Chemical, Biological and Environmental Engineering (IPCBE)*, 2013, 50: 39-44.
- AOAC International. 2005. *Official Methods of Analysis of AOAC International*. 18th Edn. AOAC International, Gaithersburg, MD.
- AOAC International. 2023. *Official Method 940.28: Free fatty acids in crude and refined oils*. In G.W. Latimer Jr. (ed.). *Official Methods of Analysis of AOAC International*. 22nd Edn. AOAC International, Rockville, MD.
- AOAC International. 2023. *Official Method 965.33: Peroxide value of oils and fats*. In G.W. Latimer Jr. (ed.). *Official Methods of Analysis of AOAC International*. 22nd Edn. AOAC International, Rockville, MD.
- Aral, S. and Beşe, A.V. 2016. Convective drying of hawthorn fruit (*Crataegus* spp.): Effect of experimental parameters on drying kinetics, color, shrinkage and rehydration capacity. *Food Chemistry*, 210: 577-584.
- Farzana, T., Mohajan, S., Saha, T., Hossain, Md. N., & Haque, Md. Z. 2017. Formulation and nutritional evaluation of a healthy vegetable soup powder supplemented with soy flour, mushroom, and moringa leaf. *Food Science & Nutrition*, 5(4): 911–920. <https://doi.org/10.1002/fsn3.476>
- Grzegory P, Piotrowski D, Bargieł K. 2013. Influence of freezing treatment, osmotic dehydration and storage time on the rehydration of vacuum dried strawberries. *Polish Society of Agricultural Engineering*, 4(148): 39–47
- Harnkarnsujarit N, Kawai K, Watanabe M, Suzuki T. 2016. Effects of freezing on microstructure and rehydration properties of freeze-dried soybean curd. *Journal of Food Engineering*, 184:10–20
- Hooda, S. and Jood, S. 2005. Organoleptic and nutritional evaluation of wheat biscuits supplemented with untreated and treated fenugreek flour. *Food Chemistry*, 90: 427-435.
- Islam, M.N. 1980. Use of Solar Energy for Development of Shelf Stable Potato Products Suitable for Bangladesh. Ph.D. Thesis, Royal Veterinary and Agricultural University, Copenhagen.
- Kashani Nejad, M., Tabil, L.G., Mortazavi, A. and Safe Kordi, A. 2003. Effect of drying methods on quality of pistachio nuts. *Drying Technology*, 21: 821-838.
- López, A., Piqué, M.T., Boatella, J., Parcerisa, J., Romero, A., Ferrá, A. and García, J. 1997. Influence of drying conditions on the hazelnut quality. I. Lipid oxidation. *Drying Technology*, 15: 965-977.
- Macedo, L.L., Vimercati, W.C., Araújo, C., Saraiva, S.H. and Teixeira, L.J.Q. 2020. Effect of drying air temperature on drying kinetics and physicochemical characteristics of dried banana. *Journal of Food Process Engineering*, 43: e13456.
- Malik, T., Saxena, M. and Sonu, K.S. 2018. Development of a ready-to-cook curry. *International Journal of Innovative Science and Research Technology*, 3: 354-357.
- Meilgaard, M., Civille, G.V. and Carr, B.T. 2014. *Sensory Evaluation Techniques*. 4th Edn. CRC Press, Boca Raton, FL.
- Ndukwu, M.C. 2009. Effect of drying temperature and drying air velocity on the drying rate and drying constant of cocoa bean. *Agricultural Engineering International: CIGR Journal*, 11: Manuscript 1091.
- Negi, N., Srihari, S.P., Wadikar, D.D., Sharma, G.K. and Semwal, A.D. 2021. Optimization of instant foxtail millet-based khichdi by using response surface methodology and evaluation of its shelf stability. *Journal of Food Science and Technology*, 58: 4478-4485.
- Pearson, D. 1970. *The Chemical Analysis of Food*. 7th Edn. Churchill Livingstone, Edinburgh.
- Rahangdale, H., Khan, M.A., Dubey, A.D. and Verma, A.K. 2015. Process standardization and nutritional quality of traditional aromatic rice and khichdi. *Trends in Biosciences*, 8: 3937-3941.
- Rajeswari, R. and Naik, R. 2023. Development of instant multi-millet fortified khichdi mix. *The Pharma Innovation Journal*, 12: 4075-4078.
- Rehman, Z.U. and Shah, W.H. 2005. Thermal heat processing effects on antinutrients, protein and starch digestibility of food legumes. *Food Chemistry*, 91: 327-331.
- Song, X., Zhang, W., Zhao, H. and Yang, F. 2019. Drying kinetics and quality characteristics of food materials during hot-air drying. *Journal of Food Processing and Preservation*, 43: e14056.
- Srikanth, K.S., Sharanagat, V.S., Kumar, Y., Bhadra, R., Singh, L., Nema, P.K. and Kumar, V. 2019. Convective drying and quality attributes of elephant foot yam (*Amorphophallus paeoniifolius*). *LWT – Food Science and Technology*, 99: 8-16.
- Wang, Y., Zhao, H., Song, X., Zhang, W. and Yang, F. 2022. Drying kinetics, physicochemical properties and sensory quality of instant foxtail millet. *Polish Journal of Food and Nutrition Sciences*, 72: 51-60.
- Westerman, P.W., White, G.M. and Ross, I.J. 1973. Modeling of thin-layer solar drying of sultana grapes: Relative humidity effects. *Transactions of the ASAE*, 16: 1136-1139.
- Yagcioglu, A., Degirmencioglu, A. and Cagatay, F. 1999. Drying characteristics of laurel leaves under different drying conditions. *Journal of Food Engineering*, 43: 145-150.
- Yaldiz, O. and Ertekin, C. 2001. Thin layer solar drying of some different vegetables. *Drying Technology*, 19: 583-596