Original Article

JHSMR Journal of Health Science and Medical Research

Influence of Sodium Reduction Using KCL and MSG on the Nutritional Profile and Consumer Acceptability of Bhutanese Cheese Curries

Tenzin Wangchuk, M.Sc.[1], Nattira On-nom, Ph.D.[2], Uthaiwan Suttisansanee, Ph.D[2], Rungrat Chamchan, M.Sc.[2], Chanakan Khemthong, B.Sc.[2], Sirinapa Thangsiri, B.Sc.[2], Chaowanee Chupeerach, Ph.D.[2]

[1]Master of Science Program in Nutrition and Dietetics, Institute of Nutrition, Mahidol University, Salaya, Phuttamonthon, Nakhon Pathom 73170, Thailand.

[2]Food and Nutrition Academic and Research Cluster, Institute of Nutrition, Mahidol University, Salaya, Phuttamonthon, Nakhon Pathom 73170, Thailand.

Received 29 August 2024 ● Revised 2 September 2024 ● Accepted 2 September 2024 ● Published online 28 February 2025

Abstract:

Objective: The rise in non-communicable diseases (NCDs); such as cardiovascular diseases, hypertension, diabetes, and cancers, in Bhutan is linked to unhealthy diets that are high in salt and saturated fats. This study aimed to reformulate popular high-sodium Bhutanese cheese curries—Shakam Datshi and Kewa Datshi—by reducing their sodium content using potassium chloride (KCl) and monosodium glutamate (MSG), while preserving traditional flavors and improving their nutritional profiles.

Material and Methods: Shakam Datshi and Kewa Datshi were identified as the highest sodium content dishes among commonly consumed Bhutanese meals. Sodium was partially replaced with KCl and MSG, and additional ingredient adjustments to align with WHO dietary guidelines. Sensory and Satiety evaluations with 50 Bhutanese panelists compared the modified recipes to the original and assessed the acceptance and fullness provided by the reformulated dishes in four healthy set menus.

Results: The reformulation achieved a 20% reduction in sodium for Shakam Datshi and over 40% for Kewa Datshi. Potassium levels significantly increased to 377.47 mg in Shakam Datshi and 651.51 mg in Kewa Datshi. Both dishes also showed reductions in total and saturated fats. Sensory evaluations indicated that the modified recipes retained high overall liking scores, similar to the originals (7.96 vs. 8.28 for Shakam Datshi and 7.48 vs. 7.90 for Kewa Datshi). Satiety assessments revealed sustained feelings of fullness.

This paper was from the 3rd Annual Health Research International Conference (AHR-iCON, August 29-30, 2024).
Contact: Chaowanee Chupeerach, Ph.D.
Food and Nutrition Academic and Research Cluster, Institute of Nutrition, Mahidol University, Salaya, Phuttamonthon, Nakhon Pathom 73170, Thailand.
E-mail: chaowanee.chu@mahidol.ac.th

J Health Sci Med Res
doi: 10.31584/jhsmr.20251159
www.jhsmr.org

Conclusion: This study demonstrated that significant sodium reduction in traditional Bhutanese cheese curries can be achieved without compromising taste or cultural authenticity. These findings provide a viable strategy to reduce hypertension in the Bhutan population through healthier dietary options.

Keywords: Bhutanese cuisine, monosodium glutamate, non-communicable diseases, potassium chloride, satiety evaluation, sensory evaluation, sodium reduction

Introduction

The rising prevalence of non-communicable diseases (NCDs) has become a critical public health issue globally, with cardiovascular diseases (CVDs) including hypertension (HT), diabetes mellitus (DM), chronic respiratory diseases, and various cancers among the most prevalent fields[1]. The World Health Organization (WHO) Global Report on HT highlights that over one billion people are affected worldwide, with only 54.0% diagnosed, 42.0% receiving treatment, and 21.0% having their condition controlled[2]. Hypertension, a silent yet deadly public health problem, is a major contributor to cardiovascular diseases[1, 2]. According to the 2019 Global Burden of Disease (GBD) study, excessive salt intake contributed to 2 million CVD-related deaths[3].

In Bhutan, like other low and middle-income countries NCDs are closely linked to shared modifiable risk factors such as unhealthy diets (excessive salt consumption, a diet high in saturated and trans fats, low intake of fruits and vegetables), physical inactivity, tobacco and alcohol consumption, and being overweight or obese[4]. The national hypertension prevalence is 17.4%, with 76.7% of cases in rural areas[5]. High sodium intake is a critical risk factor for hypertension[6,7]. Around 34.0% of Bhutanese are affected due to high-salt diets and a lack of awareness[8,9]. The 2019 NCD risk factors STEP survey reported that over 28.0% of Bhutanese have raised blood pressure (SBP ≥140 and/or DBP ≥90 mmHg) and are on medication[9]. Additionally, 51.8% use betel nuts, another risk factor for hypertension; 86.4% eat fewer than five servings of fruits and vegetables daily; 60.3% frequently consume processed foods; and 11.5% regularly eat high-sodium processed foods[8]. The mean salt intake is 8.3 g per day, based on spot urine examination[10], and around 40.7% consume more than the WHO-recommended 5 g of salt per day[7,8]. Hypertension is also highly prevalent among heavy alcohol drinkers, with 54.4%[8]. Traditional Bhutanese cuisine heavily uses salt as the primary seasoning and includes processed cheese, pickles, salted dried fish, spicy foods, and salted butter tea (Suja)[7]. This high prevalence gives rise to several life-threatening health issues, including stroke, myocardial infarction, and chronic kidney diseases[11,12].

As Bhutan navigates the balance between modernization and tradition, it is addressing hypertension through dietary improvements, like the national salt reduction strategy (2018–2023), which aims to decrease the salt intake among the population by 15.0% (7.6 g per day) by 2023[13,14], which aligns with the WHO action plan for prevention and control of NCDs[15]. Promoting healthier dietary habits is vital for reducing the burden of NCDs and enhancing the overall well-being of Bhutan's population. The country faces challenges related to inadequate dietary diversity and high consumption of refined carbohydrates, table salt, and saturated fats[7,16]. Dietary reforms are essential to combating the NCD epidemic, focusing on reducing salt intake and increasing dietary variety and nutrient density. The Centers for Disease Control and Prevention (CDC) reports that over 40.0% of daily salt intake comes from ten primary food sources, including pizza, sandwiches, deli meats,

soups, cheese, tacos, burritos, potato chips, fried chicken, scrambled eggs, and bread and WHO proposes to lower NaCl intake in these targeted foods by 35.0% by 2025[14]. The WHO recommends a healthy diet with less than 30.0% of total energy from fat, less than 10.0% from saturated fat, and under 2000 mg of sodium per day. Most people consume too much sodium, averaging 8–12 g of salt daily, while potassium intake is often below the recommended 3.5 g[17,18]. Both sodium and potassium are crucial nutrients; however, excess sodium intake and insufficient potassium intake increase the risk of hypertension[19,20].

In addition to modifiable strategies, the two leading salt replacement strategies are potassium chloride (KCl) and monosodium glutamate (MSG). The latter still contains some sodium, but both can replace some salty taste in foods while reducing net sodium levels[21,22]. Increasing KCl intake lowers blood pressure and helps prevent cardiovascular events. These salt substitutes are highlighted as are highlighted as affordable strategies[23,24].

This study utilized INMUCAL-nutrients software to analyze popular high-sodium Bhutanese cheese curry dishes and identified Kewa Datshi and Shakam Datshi as the highest in sodium. Healthier versions were developed with significantly reduced sodium content, aiming to retain the traditional cultural flavors. Sensory evaluations confirmed that the modified recipes were well-received, maintaining similar taste and satiety levels compared to the originals. These findings suggest that reducing sodium intake, essential for managing blood pressure and preventing cardiovascular diseases, can be achieved without compromising cultural culinary enjoyment.

Material and Methods

Selection of a Bhutanese cheese curry recipe for modification

An online poll was performed to identify popular Bhutanese cheese curry meals for salt reduction. The best five Bhutanese cheese curries were nutritionally assessed using INMUCAL-Nutrients V.4.0. and the two recipes containing the highest sodium were identified to formulate.

Formulation of a Bhutanese cheese curry recipe

Two cheese curry recipes were selected and reformulated using INMUCAL-Nutrients V.4.0 to reduce salt and ensure consumer acceptance. Healthy dietary recommendations were observed in the reformulation: fewer than 30.0% fat, 10.0% saturated fat, and 2000 mg salt per day[17]. Substituting cooking salt (NaCl) with combined MSG and KCl[25] lowered sodium while maintaining the perceived saltiness and liking of the dishes[22,26]. Three reformulated varieties with KCl, MSG, and both combined were sensory evaluated, with the highest-rated variants outperforming the control recipes[27].

Sensory evaluation

To compare the original and reformulated Bhutanese cheese curries, sensory evaluations were conducted with 50 untrained panelists. The panelists, healthy Bhutanese adults aged 18–40 years, were familiar with authentic Bhutanese foods and free from any illness or allergies to natural herbs and spices. Panelists used a nine-point hedonic scale to evaluate each dish's general appearance, color, odor, taste, texture, and overall liking (1=dislike extremely, 9=like extremely)[27,28]. Each 30 g sample was served in a white plastic dish, coded with random three-digit numbers, and presented in an air-conditioned test booth under consistent lighting conditions at the sensory science laboratory at the Institute of Nutrition, Mahidol University (INMU)[27]. During the evaluations, panelists received the samples with rice at a temperature of 60–65°C and were instructed to cleanse their palates with water between samples. The research followed a completely randomized block design (CRB), and the dishes with the highest overall liking scores were selected as the preferred reformulated recipes. Mahidol University Ethical Board (MU-CIRB) Ethical Review Committee accepted the study (MU-CIRB/2024-143.0904)

Creation of healthy Bhutanese set meals

Two nutritious set meals were developed based on the WHO healthy eating standards and influenced by the DASH diet protocol to ensure optimal consumption of salt and potassium[29]. Every meal comprised a reformed cheese curry and a side dish with Bhutanese red rice, parboiled rice, or whole wheat roti. Healthy people meals provide 450–550 kilocalories (Kcal) with 45.0–55.0% carbohydrate, 15.0–25.0% protein, and 25.0–35.0% fat. Daily sodium and potassium limits were 2,000 mg and 3,400 mg, respectively, with 25 g of fiber[17]. INMUCAL-Nutrients V.4.0 computed nutritional values.

Satiety evaluation

The subjective appetite of two Bhutanese healthy set menus for a healthy population was evaluated using a Visual Analog Scale (VAS). Fifty untrained Bhutanese panelists, aged 18 to 50, familiar with Bhutanese cuisine, assessed their hunger and satiety on a 7-point scale. Measurements were taken before eating, 15 minutes after consumption, and 120 minutes post-consumption to gauge initial hunger, immediate satisfaction[30], and lasting fullness[19,30].

Statistical analysis

Data were analyzed using IBM SPSS Statistics for Mac OS 14, version 29.0 (SPSS, Chicago), with sensory evaluation scores reported as means±standard deviation (S.D.). Analyses of variance (ANOVA) were employed. Duncan's multiple range test and an independent sample t-test or one-way analysis of variance (ANOVA) were implemented to compare the mean values. At a significance level of p-value<0.05, the average values were deemed to be significantly different.

Results

Selection of a Bhutanese cheese curry recipe for modification

Table 1 displays the nutritional analysis of the five most often consumed Bhutanese-style cheese curries (Datshi Tshoem) and meat stews, emphasizing significant variations in their characteristics. Kewa Datshi, a popular dish made with potatoes, chili, and cheese, contains a substantial amount of sodium (700.0 mg) and more carbs (14.6 g). Shakam Ema Datshi, a dried beef and chili cheese dish, contains the maximum amount of energy (220.3 kcal), protein (20.2 g), salt (700.9 mg), and cholesterol (65.6 mg). These two dishes, which have the greatest sodium content among the tested recipes[27], highlight the necessity of reformulating them to adhere to the healthy eating criteria set by the WHO[14]. As a result, Kewa Datshi and Shakam Datshi were chosen for restructuring.

Formulation of a Bhutanese cheese curry recipe

Following WHO criteria for a healthy diet, two Bhutanese cheese curry dishes were modified to reduce sodium to 2,000 mg daily[14]. The formulated recipes reduced sodium, fat, and saturated fat, increased potassium and dietary fiber, and were consumer-friendly. The Bhutanese

Table 1 Nutritional values of the top five mostly consumed Bhutanese-style cheese curries (1 serving size, 120 g)

Menu	Energy (kcal)	Carbohydrate (g)	Protein (g)	Total Fat (g)	Sat-Fat (g)	Sodium (mg)	Fiber (g)
Ema datshi/chili cheese	101.9	5.6	4.6	6.5	1.9	553.4	2.4
Kewa datshi/potato cheese	139.7	14.6	4.9	5.8	1.6	700.0	5.3
Shakam datshi/beef chili cheese	220.3	220.3	20.2	13.9	1.9	700.9	1.0
Shamu datshi/mushroom cheese	99.0	4.6	4.0	6.9	1.8	637.0	2.2
Nosha maru/beef stew	149.9	2.4	12.6	10.0	2.8	537.5	0.9

kcal=kilocalorie, g=gram, mg=milligram

cheese curry recipes were formulated using MSG and KCL separately and one was combined with both. They replaced Nacl with 50.0% KCL, 50.0% MSG, and another formulation with 25.0% KCl and MSG.

Sensory evaluation

The Bhutanese-style dry beef chili cheese and potato cheese curry, prepared with a combination of KCL and MSG (SD3/KD3), consistently outperformed the control dishes in sensory evaluation. The variants of KCL(SD1/KD1) and MSG(SD2/KD2) received high scores in terms of appearance, color, odor, taste, texture, and overall similarity to the control. The SD3/KD3 exhibited a comparable overall liking score (8.0) to the control (8.3), indicating its capacity to preserve sensory appeal despite a reduced salt content (Table 2). The combination of KCl and MSG was chosen over individual forms due to its balanced enhancement of sensory perception. Although the appearance and texture of the recipes were satisfactory, the flavor and overall preference were worse for both formulations including just KCl and MSG.

The reformulated versions of Shakam Datshi (SD) and Kewa Datshi (KD) were created to decrease the amount of salt while improving other nutritional aspects (Table 4).

Table 2 Sensory evaluation of four variants of Bhutanese-style dried beef chili cheese curry

Sensory attributes	Control	Reduced sodium Shakam Datshi recipe		
		SD1	SD2	SD3
Appearance	8.10±0.71^{a}	7.48±0.84^{b}	7.58±0.93^{b}	7.96±0.70^{a}
Color	8.02±0.71^{a}	7.38±0.88^{b}	7.52±1.07^{b}	7.92±0.63^{a}
Odor	7.82±1.08^{a}	7.28±1.20^{bc}	7.12±1.29^{c}	7.64±0.88^{ab}
Taste	8.42±0.61^{a}	6.96±1.14^{c}	6.80±1.20^{c}	8.00±0.86^{b}
Texture	8.00±0.83^{a}	7.12±1.27^{b}	7.26±1.03^{b}	7.80±0.99^{a}
Overall liking	8.28±0.64^{a}	7.10±1.33^{b}	6.80±1.41^{b}	7.96±0.78^{a}

Values are expressed as means±standard deviation (S.D.), Values with different superscripts indicate significant differences at p-value<0.05 using a one-way ANOVA followed by Duncan's multiple-range test
SD1=Developed dried beef cheese curry with 50.0% NaCl, 50.0% KCL, SD2=Developed dried beef cheese curry with 50.0% NaCl, 50.0% MSG, SD3=Developed dried beef cheese curry with 50.0% NaCl, 25.0%KCL & 25.0% MSG
NaCl=Sodium Chloride, KCL=Potassium Chloride, MSG=Monosodium Glutamate

Table 3 Sensory evaluation of four variants of Bhutanese-style potato cheese curry

Sensory attributes	Control	Reduced sodium Kewa Datshi recipe		
		KD1	KD2	KD3
Appearance	7.98±0.68^{a}	7.38±1.28^{b}	7.86±0.76^{a}	8.04±0.86^{a}
Color	7.86±0.73^{a}	7.40±0.95^{b}	7.80±0.78^{a}	7.56±0.70^{a}
Odor	7.78±0.71^{a}	7.12±1.21^{c}	7.30±0.86^{bc}	7.60±0.99^{ab}
Taste	7.96±0.75^{a}	6.46±1.45^{b}	6.06±1.67^{b}	7.52±1.03^{a}
Texture	7.92±0.80^{a}	7.02±1.56^{b}	7.14±1.00^{b}	7.64±1.08^{a}
Overall liking	7.90±0.81^{a}	6.56±1.40^{a}	6.26±1.58^{a}	7.48±1.27^{a}

Values are expressed as means±standard deviation (S.D.) Values with different superscripts indicate significant differences at p-value<0.05 using a one-way ANOVA followed by Duncan's multiple-range test.
KD1=Developed dried beef cheese curry with 50.0% NaCl, 50.0% KCL, KD2=Developed dried beef cheese curry with 50.0% NaCl, 50.0% MSG, KD3=Developed dried beef cheese curry with 50.0% NaCl, 25.0%KCL & 25.0% MSG
NaCl=Sodium Chloride, KCL=Potassium Chloride, MSG=Monosodium Glutamate

The sodium content in SD was decreased by approximately 20.0%, going from 550.3 mg in the original recipe to 440.9 mg in the modified version. Similarly, the reformulated KD achieved a remarkable reduction in sodium of over 40.0%, dropping from 540.3 mg in the original recipe to 313.4 mg. These changes make both recipes more in line with dietary guidelines. Concurrently, the SD formulation resulted in a large rise in potassium content, from 145.3 mg to 377.5 mg, while the KD formulation boosted it from 581.6 mg to 651.5 mg, by requirements for a healthy diet. In addition, the modified recipe demonstrated enhancements in protein and dietary fiber levels, while decreasing total and saturated fat, resulting in an overall improved nutritional composition.

Creation of healthy Bhutanese set meals

According to the WHO's dietary guidelines, two healthy Bhutanese set menus were developed, emphasizing nutritional balance and sodium reduction. The energy, carbohydrate, protein, fat, saturated fat, sodium, fiber content, and energy distribution of these set menus are illustrated in Table 5. Set Menu 1 comprises 120 g of Shakam Datshi (dried beef cheese curry), 100 g of whole wheat roti, 10 g of chile paste, 80 g of poached egg white, and 100 g of apple. Set Menu 2 includes 120 g of Kewa Datshi (potato cheese curry), 200 g of parboiled rice, 100 g of stir-fried tofu, 10 g of peppery paste, and 100g of apple. While adhering to the recommended macronutrient distribution (45.0-65.0% carbohydrates, 15.0-30.0% protein, and 20.0-35.0% fat), these meals were intended to maintain a calorie content of under 500 kcal per meal. The two healthy Bhutanese meal plans had overall liking scores of 8.0 and 8.1, corresponding to a rating of 'Like very much' as shown in Table 6. The sensory evaluation results revealed that the sensory ratings for the appearance, color, odor, flavor, and texture of both healthy set menus were rated as "like slightly" on a 9-point hedonic scale, surpassing 6. This suggests a minor preference. The consumers considered a score of 6 on a hedonic scale to be satisfactory.

Satiety evaluation

The evaluation was conducted to evaluate the satiety effects of two Bhutanese nutritious set meals. The participants' satiety levels were measured using a 7-point Visual Analog Scale (VAS) prior to consumption, 15 minutes after consumption, and 120 minutes after consumption. The data from Set Menu 1 suggests a substantial increase in satiety, as the score increased from 2.5 before consumption to 5.8 after 15 minutes. This implies that the participants were in a state of elevated appetite before the evaluation.

Table 4 Nutritional values comparing control and formulated recipes of two Bhutanese cheese curry recipes

Nutritional values (120 g)	Shakam/Dried beef cheese curry		Kewa/Potato cheese curry	
	Control	Formulated	Control	Formulated
Energy (kcal)	123.40*	121.83	154.09*	109.17
Carbohydrate (g)	2.07	3.84*	10.63*	10.01
Protein (g)	8.35	9.27*	5.63*	4.67
Total Fat (g)	9.05	7.68*	9.84*	5.56
Saturated Fat (g)	2.15*	1.79	3.53*	2.17
Potassium (mg)	145.32	377.47*	581.55	651.51*
Sodium (mg)	550.33*	440.89	540.31*	313.39
Dietary fiber (g)	0.67	1.18*	3.94	3.60

Values are expressed as means±standard deviation (S.D.), *Means significant difference at p-value<0.05

Nevertheless, the satiety level experienced a substantial decline, dropping to 4.8 after 120 minutes. Satiety increased from 2.5 when appetite was increased to 5.9 after 15 minutes in Set Menu 2 and then decreased to 4.7 after 120 minutes. This consistent pattern was observed in the data. The findings indicate that both menus effectively sustained a sense of satiety for 2 h following consumption.

Table 5 The nutrition profile and energy distribution of two healthy Bhutanese set menus

Healthy Bhutanese set menu	Energy (kcal)	CHO (g)	Pro (g)	Fat (g)	Sat Fat (g)	Sodium (mg)	K (g)	Fiber (g)	Caloric distribution (CHO:PRO:FAT)
Set 1	480	74.5	25.8	18.4	3.6	622.4	630.6	7.8	49:17:27
Set 2	491.5	66.7	24.8	16.5	3.5	475	888.2	10	57:21:32

kcal=kilocalorie, g=gram, mg=milligram, CHO=carbohydrate,PRO=protein

Table 6 Sensory evaluation of two Healthy Bhutanese set menus

Sensory attributes	Healthy Bhutanese set meals	
	1	2
Appearance	7.92±0.75	8.08±0.63
Colour	7.90±0.76	7.96±0.75
Odor	7.64±0.96	7.80±0.67
Taste	8.20±0.64	8.26±0.53
Texture	7.76±1.02	7.90±0.71
Overall liking	7.96±0.89	8.10±0.58

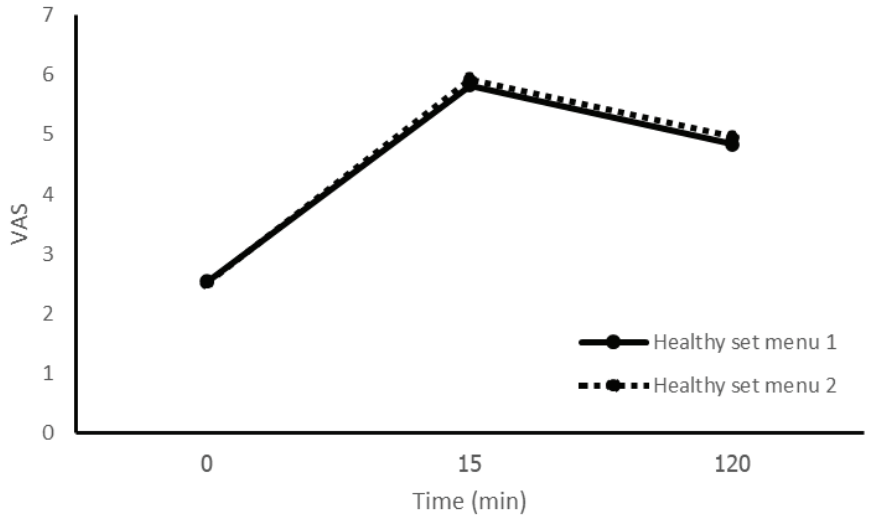

Figure 1 Satiety rating through time, before intake, and after 15 and 120 minutes intake of the healthy Bhutanese set menus

Discussion

To achieve sodium reduction, several innovative strategies were adopted. Ingredient substitution, portion size adjustments, salt crystal size reduction, encapsulation, and recipe tweaks were some of the strategies used for reformulation[31,32]. In two formulated Bhutanese cheese curry recipes, MSG and KCL substituted certain portions of sodium chloride to preserve saltiness without diminishing food acceptance[22,23]. To avoid bitterness and astringency, KCL was limited to 25.0%, MSG substituted another 25.0% of NaCl[23,26]. Also, processed cheese products with low sodium were used in the dish, reducing salt and saturated fat while retaining taste and texture[33].

Table 3 shows that the potato cheese curry formulation scored (7.5) in overall liking, beating the control's (7.9), indicating its capacity to retain a positive sensory profile. These findings support prior research showing that combined KCL & MSG sustain low-sodium food items' sensory qualities[22,34].

The two solo formulations SD1/KD1 and SD2/KD2 were least favored in terms of taste and overall like, demonstrating it alone could not compensate for the salt decrease without impacting flavor[35]. The MSG formulation differed significantly in flavor and overall liking, especially for the dry beef chili cheese curry, scoring (6.8) against (8.3) for the control. The SD3/KD3 appears to overcome these sensory downsides, creating a harmonic improvement that mimics full-sodium versions. KCl and MSG increase sensory qualities and balance the taste profile, making them a superior option for minimizing salt in food formulations, according to previous research[31,35]. The SD3/KD3 formulations were the best reduced-sodium solutions for Bhutanese-style dry beef chili cheese curry and potato cheese curry.

The significant reduction in the sodium content of SD3, nearly 20.0%, makes it more suitable for dietary guidelines that emphasize lower sodium intake to reduce cardiovascular risk[3,12]. The improvement in the potassium content in formulated recipes also balances recommendations on sodium reduction with adequate potassium levels for improved cardiovascular health[20].

This substantial decrease supports efforts to meet health guidelines for sodium consumption[14]. Furthermore, the increase in potassium is beneficial for counteracting the effects of sodium and supporting heart health[26]. The reformulated KD also showed notable reductions in total fat and saturated fat, while slightly reducing protein levels. These changes reflect a significant improvement in the overall nutritional quality of the dish, making it a healthier option without sacrificing essential nutrients[3]. In addition, the analysis of healthy Bhutanese set menus shows that both set menus effectively reduce sodium intake while enhancing other nutritional profiles. Set Menu 1 delivers 622.4 mg of sodium and 7.8 g of dietary fiber, while Set Menu 2 offers a lower sodium content of 475 mg and a higher fiber content of 10 g. These sodium levels represent a significant reduction from typical Bhutanese dishes, aligning with WHO's sodium intake guidelines aimed at reducing hypertension and cardiovascular disease risks[3,14]. Additionally, the potassium content is notably high, with 630.6 mg in Set Menu 1 and 888.2 mg in Set Menu 2, contributing to balanced electrolyte levels and supporting cardiovascular health[18,24]. The inclusion of whole grains and fiber-rich components, like whole wheat roti and parboiled rice, further enhances these meals' health benefits, supporting digestive health and aiding in maintaining optimal body weight[17,29]. These well-balanced set menus demonstrate that traditional Bhutanese cuisine can be adapted to meet modern health guidelines without compromising on flavor or nutritional value[32].

Furthermore, the high VAS score of high satiety from two Bhutanese healthy set menus, one with SD3 as a main dish served with whole wheat Roti and another KD3 served with parboiled rice, can be attributed to their unique nutritional composition. Key components like boiled

egg whites, cheese, and fried tofu are rich in protein, which significantly enhances feelings of fullness by increasing levels of amino acids and hunger-suppressing hormones[36]. Incorporating low-glycemic index (GI) foods such as whole wheat roti and parboiled rice also contributes to prolonged satiety. These foods slow glucose absorption and prevent rapid insulin spikes, leading to sustained energy release and extended satiety[37-39]. The high fiber content in apples and whole grains further supports prolonged fullness by slowing digestion and gastric emptying[40]. Fiber's interaction with gut microbiota produces short-chain fatty acids, which help regulate appetite and energy balance[39]. Beyond nutritional factors, the palatability of the dishes, along with the eating environment, significantly influences satiety. Enjoyable and appealing meals, combined with a supportive dining atmosphere, enhance the overall satisfaction and fullness experienced after eating[38, 39]. These findings confirm that Bhutanese set meals are effective in inducing and maintaining satiety and encouraging healthy eating habits.

Conclusion

This study successfully reformulated two popular Bhutanese dishes, Shakam Datshi (dried beef cheese curry) and Kewa Datshi (potato cheese curry), to align with WHO guidelines for sodium reduction and nutritional balance. The sodium content in Shakam Datshi was reduced by 20.0%, from 550.3 mg to 440.9 mg, and in Kewa Datshi by over 40.0%, from 540.3 mg to 313.4 mg. Potassium levels were significantly increased, enhancing the dishes' cardiovascular benefits (377.5 mg in Shakam Datshi and 651.5 mg in Kewa Datshi). Additionally, both reformulated recipes showed reductions in total and saturated fats, while increasing protein and dietary fiber, contributing to a healthier overall nutritional profile.

The sensory evaluation indicated that the combined use of potassium chloride (KCL) and monosodium glutamate (MSG) in the reformulated recipes effectively preserved their sensory qualities. Both Shakam Datshi and Kewa Datshi with KCL & MSG (SD3/KD3) received high overall liking scores comparable to their full-sodium controls, demonstrating their ability to maintain flavor and consumer acceptance. Furthermore, the satiety assessment showed that these set menus significantly enhanced and sustained feelings of fullness for up to 2 h after consumption, with satiety scores rising from around 2.5 before eating to over 5.8 fifteen minutes after eating and maintaining scores above 4.6 after 120 minutes. These findings suggest that the reformulated Bhutanese dishes meet modern health guidelines and retain their traditional appeal, supporting the adoption of healthier eating habits without sacrificing satisfaction or nutritional value.

References

1. WHO. Noncommunicable diseases. [homepage on the Internet] Geneva: WHO; 2023 [cited 2024 Oct 6]. Available from: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases.
2. Kario K, Okura A, Hoshide S, Mogi M. The WHO Global report 2023 on hypertension warning the emerging hypertension burden in globe and its treatment strategy. Hypertens Res 2024;47:1099-102.
3. Wang K, Jin Y, Wang M, Liu J, Bu X, Mu J, et al. Global cardiovascular diseases burden attributable to high sodium intake from 1990 to 2019. J Clin Hypertens (Greenwich) 2023;25:868-79.
4. Pengpid S, Peltzer K. Trends in behavioral and biological risk factors for non-communicable diseases among adults in Bhutan: results from cross-sectional surveys in 2007, 2014, and 2019. Front Public Health 2023;11:1192183.
5. Wangdi K, Jamtsho T. Prevalence and predisposing factors for self-reported hypertension in Bhutanese adults. Nepal J Epidemiol 2020;10:830-40.
6. Jiang K, He T, Ji Y, Zhu T, Jiang E. The perspective of hypertension and salt intake in Chinese population. Front Public Health 2023;11:1125608.
7. Dorji T, Dzed L, Yangchen P, Pelzom D, Gurung M, Pem D, et al. National Nutrition Survey 2015. Thimphu: Ministry of Health, Bhutan; 2015.

8. Ministry of Health (Bhutan). Bhutan STEPS Noncommunicable Disease Risk Factors Survey 2019. [homepage on the Internet] Seattle: WHO NCD Microdata Repository; 2021. [cited 2024 Jun 11] Available from: https://ghdx.healthdata.org/record/bhutan-steps-noncommunicable-disease-risk-factors-survey-2019.
9. Pelzom D, Isaakidis P, Oo MM, Gurung MS, Yangchen P. Alarming prevalence and clustering of modifiable noncommunicable disease risk factors among adults in Bhutan: a nationwide cross-sectional community survey. BMC Public Health 2017;17:1-11.
10. Afroza U, Abrar AK, Nowar A, Akhtar J, Mamun MAA, Sobhan SMM, et al. Salt intake estimation from urine samples in south asian population: scoping review. Nutrients 2023;15.
11. Usui I. Common metabolic features of hypertension and type 2 diabetes. Hypertens Res 2023;46:1227-33.
12. Zoccali C, Mallamaci F, Adamczak M, de Oliveira RB, Massy ZA, Sarafidis P, et al. Cardiovascular complications in chronic kidney disease: a review from the european renal and cardiovascular medicine working group of the european renal association. Cardiovasc Res 2023;119:2017-32.
13. Ghimire K, Mishra SR, Satheesh G, Neupane D, Sharma A, Panda R, et al. Salt intake and salt-reduction strategies in South Asia: from evidence to action. J Clin Hypertens 2021;23:1815-29.
14. WHO. Sodium Reduction. [homepage on the Internet] Geneva: WHO; 2023. [cited 2024 June 11]. Available from: https://www.who.int/news-room/fact-sheets/detail/salt-reduction.
15. WHO. Action plan for the prevention and control of noncommunicable diseases in South-East Asia, 2013–2020: extended to 2030. [homepage on the Internet] Geneva: WHO; 2022. [cited 2024 Jun 6]. Available from: https://www.who.int/publications/i/item/sea-ncd-89.
16. Ndubuisi NE. Noncommunicable diseases prevention in low-and middle-income countries: an overview of health in all policies (HiAP). Inquiry 2021;58:0046958020927885.
17. WHO. Healthy diet. [homepage on the Internet] Geneva: WHO; 2020 [cited 2024 Jun 6]. Available from: https://www.who.int/news-room/fact-sheets/detail/healthy-diet.
18. Xu X, Zeng L, Jha V, Cobb LK, Shibuya K, Appel LJ, et al. Potassium-enriched salt substitutes: a review of recommendations in clinical management guidelines. Hypertens 2024;81:400-14.
19. Sun N, Jiang Y, Wang H, Yuan Y, Cheng W, Han Q, et al. Survey on sodium and potassium intake in patients with hypertension in China. J Clin Hypertens (Greenwich). 2021;23:1957-64.
20. Kim BS, Yu M-Y, Shin J. Effect of low sodium and high potassium diet on lowering blood pressure and cardiovascular events. Clin Hypertens 2024;30:2.
21. Tan HL, Tan TC, Easa AM. The use of salt substitutes to replace sodium chloride in food products: a review. Int J Food Sci Technol 2022;57:6997-7007.
22. Walker JC, Dando R. Sodium replacement with kcl and msg: attitudes, perception and acceptance in reduced salt soups. Foods 2023;12:2063.
23. Cepanec K, Vugrinec S, Cvetković T, Ranilović J. Potassium chloride-based salt substitutes: a critical review with a focus on the patent literature. Compr Rev Food Sci Food Saf 2017;16:881-94.
24. Greer RC, Marklund M, Anderson CA, Cobb LK, Dalcin AT, Henry M, et al. Potassium-enriched salt substitutes as a means to lower blood pressure: benefits and risks. Hypertens 2020;75:266-74.
25. Dunteman AN, McKenzie EN, Yang Y, Lee Y, Lee SY. Compendium of sodium reduction strategies in foods: A scoping review. Compr Rev Food Sci Food Saf 2022;21:1300-35.
26. van Buren L, Dötsch-Klerk M, Seewi G, Newson RS. Dietary impact of adding potassium chloride to foods as a sodium reduction technique. Nutrients 2016;8:235.
27. Chupeerach C, Cho EM, Suttisansanee U, Chamchan R, Khemthong C, On-nom N. Reducing calories, fat, saturated fat and sodium in myanmar recipes: effect on consumer acceptance. NFS J 2021;25:51-5.
28. Meilgaard MC, Carr BT, Civille GV. Sensory evaluation techniques: Boca Raton: CRC Press; 1999.
29. Campbell AP. Dash eating plan: an eating pattern for diabetes management. Diabetes Spectr 2017;30:76-81.
30. Abdel-Moemin AR. Consumer satisfaction and nutrient profile of reformulated dry soups. Agricultura 2014;11:27-34.
31. Nurmilah S, Cahyana Y, Utama GL, Aït-Kaddour A. Strategies to reduce salt content and its effect on food characteristics and acceptance: a review. Foods 2022;11:3120.
32. Hoppu U, Hopia A, Pohjanheimo T, Rotola-Pukkila M, Mäkinen S, Pihlanto A, et al. Effect of salt reduction on consumer acceptance and sensory quality of food. Foods 2017;6:103.
33. Cruz AG, Faria JA, Pollonio MA, Bolini HM, Celeghini RM, Granato D, et al. Cheeses with reduced sodium content: Effects

on functionality, public health benefits and sensory properties. Trends Food Sci Technol 2011;22:276-91.

34. Lorén N, Niimi J, Höglund E, Albin R, Rytter E, Bjerre K, et al. Sodium reduction in foods: challenges and strategies for technical solutions. J Food Sci 2023;88:885-900.
35. Sinopoli DA, Lawless HT. Taste properties of potassium chloride alone and in mixtures with sodium chloride using a check-all-that-apply method. J Food Sci 2012;77:S319-22.
36. Halton TL, Hu FB. The effects of high protein diets on thermogenesis, satiety and weight loss: a critical review. Am Coll Nutr 2004;23:373-85.
37. Chang KT, Lampe JW, Schwarz Y, Breymeyer KL, Noar KA, Song X, et al. Low glycemic load experimental diet more satiating than high glycemic load diet. Nutr Cancer 2012;64:666-73.
38. Benelam B. Satiation, satiety and their effects on eating behaviour. Nutr Bull 2009;34:126-73.
39. Tremblay A, Bellisle F. Nutrients, satiety, and control of energy intake. Appl Physiol Nutr Metab 2015;40:971-9.
40. Warrilow A, Mellor D, McKune A, Pumpa K. Dietary fat, fibre, satiation, and satiety—a systematic review of acute studies. Eur J Clin Nutr 2019;73:333-44.