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Original Article

One-Year Prospective Human Study on the Impact of Fermented Lingonberry Juice Mouthwash on Salivary Characteristics

Aada Soininen[1]*, Jere Valkama[1]

[1]Department of Oral and Maxillofacial Diseases, Head and Neck Center, Faculty of Medicine, University of Helsinki and Helsinki University Hospital, 00290 Helsinki, Finland.

***E-mail** ✉ aada.s07@hotmail.com

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ABSTRACT

This one-year prospective intervention study evaluated the influence of fermented lingonberry juice (FLJ) mouthwash on various salivary parameters. Twenty-five adults participated, using 10 mL of FLJ as a mouth rinse for 30 seconds daily over a six-month period, alongside their regular oral hygiene practices. Clinical oral examinations and sample collections were carried out at baseline, six months, and one year. Measurements included resting and stimulated salivary flow rates, resting saliva pH, and buffering capacity of stimulated saliva. Participants also completed questionnaires assessing perceived mouth dryness at each visit. The use of FLJ mouthwash resulted in improvements across all five salivary indicators, with statistically significant differences observed throughout the study according to omnibus testing. Questionnaire analysis further demonstrated a reduction in xerostomia symptoms following FLJ use. Overall, daily rinsing with FLJ enhanced salivary secretion, buffering ability, and pH, suggesting that FLJ mouthwash can serve as a safe, supportive addition to daily oral care by promoting oral health, protecting dental and mucosal tissues, and alleviating dry mouth discomfort.

Keywords: Xerostomia, Resting saliva, Fermented lingonberry juice, Salivary buffering capacity, Stimulated saliva, Dry mouth

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Introduction

Saliva plays a vital role in preserving and regulating oral health through numerous functions. It lubricates and shields the oral mucosa, neutralizes acid fluctuations following food intake, contributes to enamel and dentin remineralization processes, exhibits antimicrobial activity via both immune and non-immune mechanisms, enhances taste perception, and initiates digestion. Whole saliva consists of mixed secretions from the major salivary glands (parotid, submandibular, and sublingual), minor glands located in the lips, tongue, palate, cheeks, and pharynx, as well as gingival crevicular fluid, containing minerals, proteins, and mucins [1]. Conditions such as diabetes mellitus, Sjögren's syndrome, medication use, or radiotherapy can impair salivary gland function, resulting in xerostomia, microbial imbalance, dental caries, periodontal problems, or mucosal infections like candidiasis [2–6]. Under normal conditions, salivary pH ranges between 6 and 7, with unstimulated flow rates of 0.3–0.4 mL/min and stimulated flow rates between 1 and 3 mL/min. Buffering capacity typically measures 10–12. Hyposalivation is defined by a resting flow rate below 0.1 mL/min and a stimulated rate under 0.7 mL/min. Eating and drinking influence both salivary pH and secretion, with buffering mechanisms restoring equilibrium within 5–15 minutes depending on the acidity, sugar content, and frequency of intake [7, 8]. A non-bacterial pellicle layer coats teeth and serves as a barrier against pH fluctuations. However, frequent consumption of fermentable carbohydrates or acidic beverages in the presence of acidogenic microbes can lead to enamel demineralization below the critical pH threshold of 5.5 identified by R.M. Stephan [9]. While saliva naturally counteracts this process, reduced buffering capacity and low pH heighten erosion risk.

Options to enhance salivary flow remain limited. Topical products such as lubricating gels, toothpastes, sprays, or artificial saliva may ease the discomfort of xerostomia by serving as stimulants or substitutes [10]. Chewing xylitol gum or consuming acidic agents can temporarily boost secretion. Pharmacologic stimulants like pilocarpine and cevimeline act systemically as parasympathomimetics but often produce adverse effects and are unsuitable for patients with iritis, narrow-angle glaucoma, peptic ulcers, uncontrolled asthma, or those taking β-blockers [11, 12]. Natural bioactive agents have been explored for oral health applications. Lingonberries are rich in phenolic compounds known for antioxidative, anti-inflammatory, and antimicrobial activities [13]. Earlier in vitro and clinical research has shown that fermented lingonberry juice (FLJ) mouthwash exerts antimicrobial, anti-inflammatory, and anti-proteolytic effects [14, 15]; however, its influence on salivary parameters has not been previously assessed.

This prospective clinical study therefore aimed to investigate how daily use of FLJ mouthwash affects salivary secretion rate, pH, and buffering capacity in adults attending two private dental clinics in Finland. The study hypothesized that incorporating FLJ as a daily adjunct to oral hygiene would enhance salivary output and buffering strength without reducing pH, thereby helping to manage hyposalivation symptoms safely.

Materials and Methods

A total of 25 adults aged 28–91 years (mean 65.29 ± 16.23; 10 men and 15 women) were randomly recruited from private dental practices in Helsinki and Joensuu, Finland. The study was conducted from June 2020 to June 2021. Participants included healthy individuals or those with well-managed systemic conditions, possessing adequate periodontal health, with or without xerostomia, and free from oral mucosal inflammation. Some participants used removable prostheses (one full upper denture and three partial upper dentures). Medical histories revealed conditions such as cardiovascular disease and diabetes mellitus but excluded autoimmune disorders. Participants were ineligible if they used mouthrinses other than FLJ (e.g., chlorhexidine) or were on antibiotics during the study.

Measurements of resting salivary flow rate and pH, as well as stimulated salivary flow rate and buffering capacity, were performed using the Saliva-Check BUFFER test kit (GC America Inc., Illinois, USA) at baseline, six months, and twelve months. Participants were instructed to refrain from eating, drinking, or brushing their teeth for one hour prior to appointments, and all collections occurred in the afternoon. For resting saliva, participants first swallowed any residual saliva and then allowed saliva to passively drain into a collection cup for five minutes without spitting or moving facial muscles. A rate above 0.3 mL/min was considered normal, 0.1–0.3 mL/min low, and below 0.1 mL/min extremely low.

The test kit used pH indicator paper and buffer capacity strips. Each was thoroughly moistened with resting saliva via pipette, excess removed on a paper towel, and color changes compared to a reference chart within the manufacturer's time frame to obtain numerical values. Buffering scores (0–12) were interpreted as follows: 0–5 extremely low, 6–9 low, and 10–12 normal/high. Salivary pH values (scale 5.0–7.8, interval 0.2) were classified as 5.0–5.8 highly acidic, 6.0–6.6 moderately acidic, and 6.8–7.8 normal [16]. Stimulated saliva was collected for five minutes after chewing wax; secretion rates above 1 mL/min were deemed normal, 0.7–1 mL/min low, and below 0.7 mL/min extremely low.

Medical conditions and medications were documented, and drugs associated with xerostomia were categorized based on their salivary inhibition strength as outlined by Wolff *et al*. [2]. At each study point, participants completed a xerostomia questionnaire **(Table 1)** consisting of yes/no questions addressing dry mouth sensations, with positive responses scored and summed for each participant.

Table 1. Questionnaire on Xerostomia Sensations

1. Do you experience dryness in your mouth after meals?
2. Do you find swallowing difficult?
3. Can you consume dry foods such as bread or biscuits without needing to drink?
4. Do you feel that your saliva production is insufficient?
5. How frequently do you wake up during the night due to a dry mouth?

Participants used 10 mL of fermented lingonberry juice (FLJ; Lingora®, Vantaa, Finland) [14] as a mouth rinse for 30 seconds daily over a six-month period, alongside their routine oral hygiene practices, followed by a six-month washout phase without FLJ use. The mouthwash contained 0.219% (w/w) phenolic compounds and had a pH of 2.77. Throughout the study, participants maintained regular oral care using non-professional toothpaste, while professional topical fluoride treatment was applied at each evaluation point. Ethical approval for the research was obtained from the Stockholm Community Ethics Committee, Sweden (2016-08-24/2016/1:8 and 2016-1-24), and from the Helsinki University Central Hospital, Finland (360/13/03/00/13 and 51/13/02/2009). All participants provided written informed consent prior to enrollment. Salivary parameters—including resting salivary flow, resting saliva pH, stimulated saliva rate, and buffering capacity—along with subjective reports of dry mouth, were recorded for 21 individuals at baseline, six months, and twelve months. Statistical analysis of overall changes across time points was performed using the non-parametric Friedman test, followed by pairwise post hoc comparisons using Bonferroni-adjusted Wilcoxon signed-rank tests. Analyses were carried out using SPSS version 27 (IBM Corp., Armonk, NY, USA) and the rmcorr package (version 0.4.1) in R software version 3.6.3, with a significance level set at $p < 0.05$. Based on one-way repeated-measures ANOVA parameters (effect size = 0.40, $\alpha = 0.05$, 95% power), a sample size of at least 18 participants was deemed adequate, as no prior FLJ studies existed for effect size estimation.

Results and Discussion

Of the 25 recruited participants, 21 adhered to the study protocol, using 10 mL of FLJ once daily as instructed, and were included in the final analysis. Participant numbers and age distribution are illustrated in **Figure 1**. All subjects completed the study. One individual exhibited an extremely low resting salivary flow rate, preventing pH measurement. Four participants deviated from the prescribed regimen: one used 5 mL daily, two used 10 mL irregularly, and one used 20 mL daily. **Table 2** presents participant characteristics, systemic conditions, and medication profiles with frequency distributions (%). The study cohort reflects a representative sample of generally healthy, middle-aged Scandinavian dental patients who typically attend annual dental check-ups.

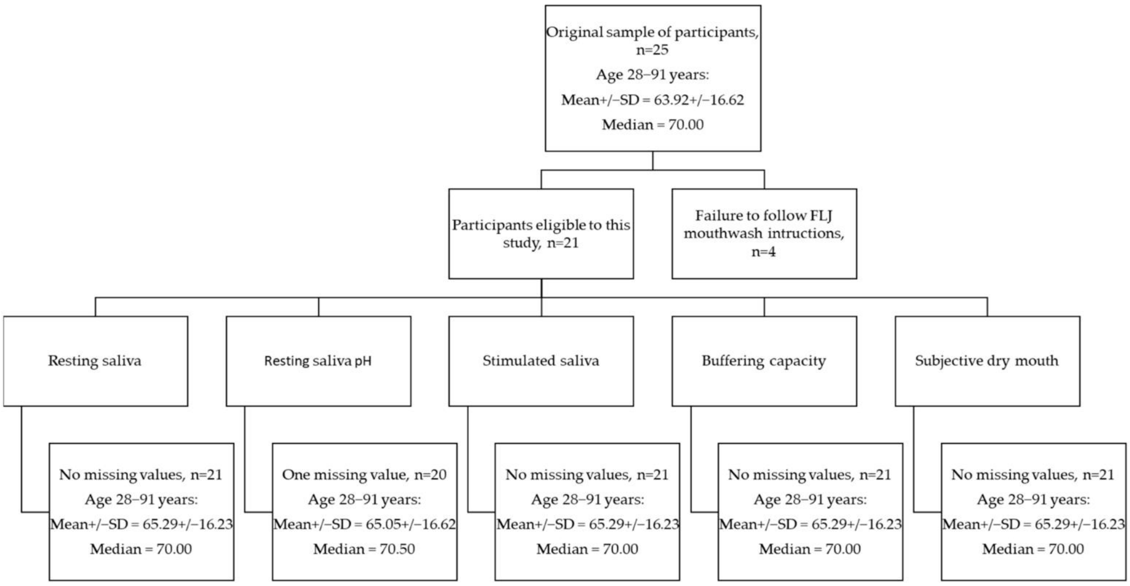


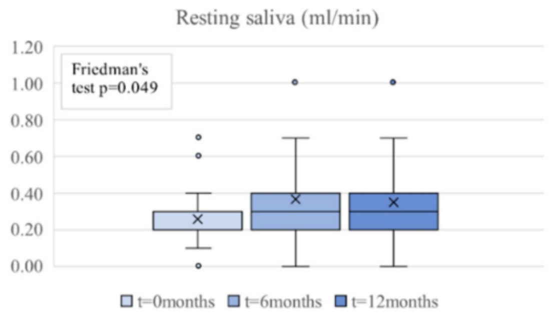
Figure 1. Flowchart of sample number and age of participants in the current study.

Table 2. Patient characteristics.

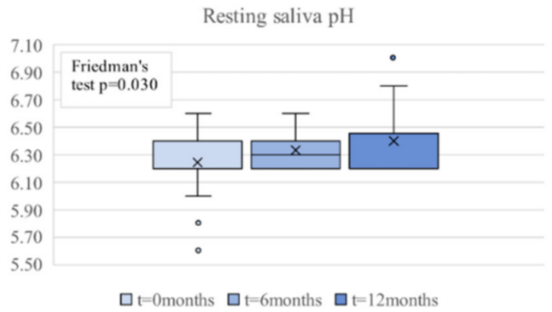
Age (mean ± standard deviation)	65.29 ±
Gender (female/male,%)	16.23 years
Smoking (yes%)	61.9/38.1%
Diseases (mean, range)	19.0%
Medications (mean, range)	1.76, 0–4
Medications inducing xerostomia (mean,	2.95, 0–9
range)	1.33, 0–4

Diseases were categorized based on the International Statistical Classification of Diseases and Related Health Problems [17] into groups affecting the endocrine and metabolic systems, mental and behavioral health, circulatory system, and respiratory system. Medications with moderate to strong evidence of causing xerostomia primarily included those prescribed for endocrine and metabolic disorders (such as diabetes), circulatory conditions (such as hypertension), and mental or behavioral illnesses [2].

Figure 2 presents the outcomes for the measured salivary parameters. The use of FLJ mouthwash produced improvements across all five parameters, and omnibus testing confirmed that these changes were statistically significant across the three evaluation time points.



a)



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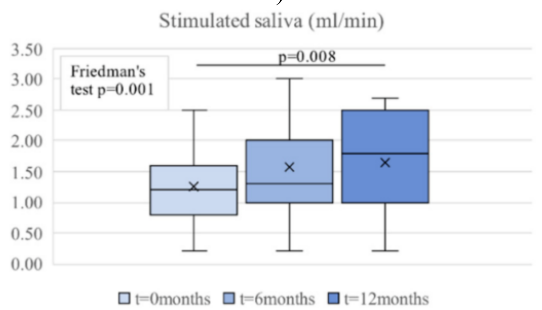

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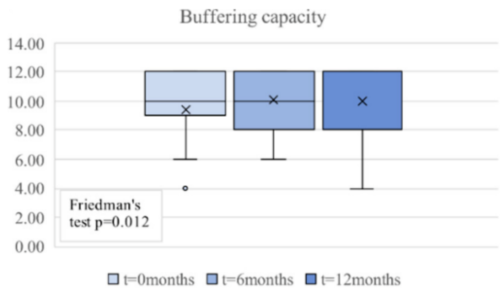

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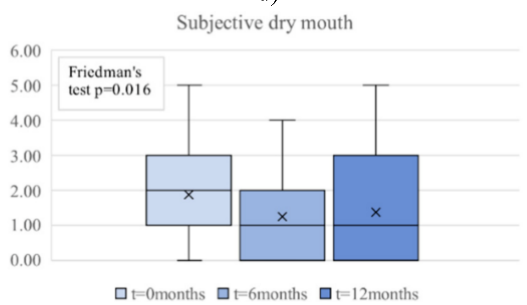

e)

Figure 2. Boxplots present the variations in (a) resting salivary flow, (b) resting saliva pH, (c) stimulated salivary flow, (d) buffering capacity, and (e) perceived mouth dryness at three measurement intervals (baseline, 6 months, and 12 months; n = 21). Statistical evaluation across the timepoints employed Friedman's test, followed by Bonferroni-adjusted Wilcoxon signed-rank comparisons. Each boxplot illustrates the median, mean (x), interquartile range, and outlier values (o).

- Resting saliva flow showed a marked increase from initially low readings to normal levels during the FLJ usage period and sustained this improvement throughout the subsequent washout phase **(Figure 2a)**.
- Resting saliva pH demonstrated a gradual and consistent rise over the course of the study **(Figure 2b)**.
- Stimulated saliva flow exhibited an upward trend during the six months of FLJ rinsing and continued to improve even after discontinuation **(Figure 2c)**.
- Buffering capacity progressed from near the low threshold to within the normal range while participants were using FLJ and remained stable afterward **(Figure 2d)**.
- At the start of the study, only weak associations were found between self-reported dry mouth symptoms and resting/stimulated salivary flow, saliva pH, and buffering capacity ($r = -0.432$, $p = 0.05$; $r = -0.482$, $p = 0.027$; $r = -0.357$, $p = 0.123$; and $r = -0.287$, $p = 0.207$, respectively). Questionnaire data revealed that sensations of dryness declined during FLJ use and stayed reduced after cessation, inversely correlating with resting and stimulated salivary flow and pH—indicating that improvements in these parameters corresponded with diminished xerostomia symptoms.
- The number of participants within each category of measured variables throughout the study is detailed in **Table 3**.

Table 3. Frequencies of participants in each classification of variables during the study.

Saliva sampling (months)	**0**	**6**	**12**
Resting saliva flow (N)			
Extremely low (<0.1 ml/min)	4	2	3
Low (0.1–0.7ml/min)	13	15	14
Normal (>0.3 ml/min)	8	8	8
Stimulated saliva (N)			
Extremely low (<0.7 ml/min)	2	1	2
Low (0.7–1 ml/min)	10	8	6
Normal (>1 ml/min)	13	16	17

Resting saliva pH (N)			
Highly acidic (5–5,8)	2	0	0
Moderately acidic (6–6.6)	20	24	20
Healthy (6.8–7.8)	2	0	4
Buffering capacity (N)			
Very low (0–5)	2	0	1
Low (6–9)	7	8	5
Normal/high (10–12)	16	17	19

It is worth noting that four of the twenty-five participants did not adhere to the study instructions, and consequently, their buffering capacity values did not exhibit statistically significant variations. No cases of mucosal irritation or erosive lesions were observed throughout the intervention, and participants reported no adverse reactions to the FLJ mouthwash.

Maintaining adequate salivary flow, buffering capacity, and pH is fundamental for preserving oral tissue integrity and dental health. These parameters are interdependent, as decreased flow rate leads to lower pH and reduced buffering potential [18]. Individuals suffering from chronic diseases such as diabetes, asthma, or COPD often experience compromised salivary function, reflected in reduced flow rate, pH, and buffering capacity [19, 20]. Alterations in these salivary properties have also been associated with increased risk of caries, periodontal disease, and oral candidiasis among the elderly, adolescents, and those with xerostomia [5, 21]. Autoimmune conditions like Sjögren's syndrome further exacerbate oral dryness through diminished salivary secretion [22]. The present cohort can be considered a representative sample of the Scandinavian middle-aged outpatient population in terms of demographic, lifestyle, and health characteristics. In this study, the subjective feeling of oral dryness correlated strongly with both unstimulated and stimulated saliva flow rates and with resting salivary pH. One of the most effective ways to alleviate dry mouth symptoms is by stimulating salivary secretion [23]. The findings of this research demonstrated that using FLJ mouthwash significantly enhanced both stimulated and resting saliva flow rates, as well as resting saliva pH and buffering capacity, during the treatment period.

The results also indicate that FLJ helps sustain salivary pH within a favorable range, unlike CHX, which has been previously reported to lower both pH and buffering ability [24], potentially fostering acidic conditions that support the growth of oral pathogens. Since enamel and dentin remineralization depends on the balance between demineralization and remineralization processes, maintaining proper pH is crucial [25]. Liquids undergo buffering faster than solids, and the inhibition of MMP activity—linked to caries and erosion—has been demonstrated using agents such as chlorhexidine, ferrous sulfate, and green tea [26, 27]. FLJ, with its strong anti-inflammatory [13, 15] and antimicrobial properties comparable to CHX [14, 15, 28, 29], has also been shown in previous in vitro experiments to block Candida glabrata-induced activation of pro-MMP-8 [30].

Extensive in vitro research highlights the multifunctional properties of lingonberry-derived polyphenols, including antibacterial [31–33], antiviral [34], antioxidant [35–42], anti-inflammatory [30, 35], and anticancer activities [43–46]. Animal studies have further demonstrated the anti-inflammatory and anti-atherothrombotic potential of lingonberry juice, along with metabolic benefits such as improved glucose regulation, lipid metabolism, and brain function, and reduced obesity and intestinal inflammation [47–50]. Human studies have corroborated its influence on glucose, insulin, and free fatty acid responses following the consumption of lingonberry-based products [51, 52]. Moreover, in vivo oral studies with FLJ have shown a reduction in Streptococcus mutans and Candida counts and anti-inflammatory benefits [15]. Since saliva plays a vital role in mucosal lubrication and innate immune defense, it has been proposed that mucin glycoprotein composition may influence infection susceptibility, progression, and even serve as a biomarker for disease prognosis, including COVID-19 [53]. Pathogen-derived proteases can alter these glycoproteins, facilitating infection, but lingonberry polyphenols have demonstrated antiviral mechanisms that may counteract such processes [54].

Given the crucial role of saliva secretion in oral homeostasis, the natural composition and safety profile of FLJ make it well suited for long-term oral care use. FLJ, derived from fermented lingonberries, can be safely ingested and lacks additives, side effects, or known drug interactions. Ten milliliters of FLJ approximately correspond to 1 deciliter of lingonberries, aligning with the general dietary recommendation of consuming 250 grams of fruits and berries daily [55]. The fermentation process significantly reduces its natural sugar content, making it a healthier alternative to unfermented juice. In this study, fluoride application was professionally standardized during sampling sessions, although the lack of control over the participants' toothpaste selection constitutes a minor limitation.

Efforts to develop interventions for dry mouth focus on several approaches, such as replacing lost saliva with artificial substitutes, using moisture-retaining surface agents, mechanically stimulating saliva through chewing gum, or employing pharmacological sialagogues. However, these methods typically provide only temporary relief, may cause side effects, and do not truly stimulate natural salivary secretion. Interest has grown in natural products for managing xerostomia [56]. A limitation of many existing products is their acidic composition, which can irritate oral mucosa, lower salivary pH, harm teeth, or fail to enhance salivary flow [57]. The exact mechanisms by which FLJ influences salivary parameters remain unclear, but possible explanations include stimulation of salivary gland activity through its acidic components, leading to increases in saliva volume, pH, and buffering capacity. Additionally, the diverse polyphenols in FLJ provide antioxidant, anti-inflammatory, anti-proteolytic, and antimicrobial protection of the oral mucosa, potentially improving saliva characteristics by modulating the oral microbiome and its metabolic products.

Conclusion

This prospective human intervention study demonstrated for the first time that daily use of 10 mL of FLJ for six months enhanced salivary secretion rates, buffering capacity, and pH while reducing xerostomia. These beneficial effects persisted throughout the six-month washout period. The observed improvements suggest that FLJ may serve as a safe, natural adjunct for alleviating dry mouth symptoms. Given the critical role of salivary parameters in preventing caries, periodontal disease, and oral candidiasis, further larger-scale, randomized, placebo-controlled trials are needed to confirm these findings.

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Conflict of Interest: None

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Ethics Statement: None

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