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# Profile Optimisation for the Determination of Pasting Properties of Bamboo Seed Flour

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## Abstract

The present investigation was to optimise the pasting profile specific to the determination of pasting properties of bamboo seed flour using Rapid Visco Analyser (RVA). The RVA test procedure profile conditions such as shear rate (A), flour concentration (B) and initial/final temperature (C) for bamboo seed flour in standard 1 profile (TCW software) was optimized using Central Composite Rotatable Design of Response Surface Methodology. The center point in five level factor for independent variables of A, B and C was 160 rpm, 4g and 50$^0$C respectively. The shear rate, starting and ending temperature had negative significant influence ($p<0.01$) on RVA viscosity parameters while flour concentration showed positive significant effect ($p<0.01$) on RVA viscosity parameters. Interactively, flour concentration and temperature suggested significant negative influence (at $p<0.05$) on all determined RVA viscosity parameters. On the basis of maximum peak (PV) and Final Viscosity (FV), 123 rpm as rotational speed of paddle, 3.9g as flour concentration mixed in 25 ml of water (15.6%) and 32.3°C as starting and ending temperature in standard 1 profile of RVA test procedure was considered as valid profile conditions for the determination of pasting properties of bamboo seed flour.

**Keywords:** Bamboo Seed Flour, Central Composite Rotatable Design, Pasting Properties, Rapid Visco Analyser, Standard 1 Profile

## 1. Introduction

Bamboo (Bambusa arundinacea) belongs to family Poaceae and subfamily Bambusoideae. Giant bamboos are the largest members of the grass family. Bamboo is one of the precious plant resources of earth. It played a significant role in human civilization since ancient times and still contributing to the substance of over 2 billion people living in the tropical and subtropical belts in Asia, Latin America and Africa. Traditional uses of bamboo are differing from region to region and people to people, since time immemorial, bamboo being used as fuel, food, housing and shelter by indigenous communities [1].

Totally 26 bamboo species are used for edible purpose in Pacific region of Asia i.e. Southern Western Ghats of Kanyakumari district. The tribals have a vast knowledge about the utilization of these bamboo resources for their day-to-day life [2]. However, there is a lack of information about the uses of bamboo seeds and the seeds of Bambusa arundinaceous, found to be utilized as a food grain among the tribals of Kanyakumari district. This is the commonest bamboo in the region, commonly called Moongil (in Tamil), the grains of the bamboo are locally known as Moongil Arisee (in Tamil) that means bamboo rice. The collected seeds were cleaned in water and boiled like rice, consumed with fish curry and vegetables by indigenouspeople as a substitute of rice and also rich in

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nutrient and nutritive quality is slightly greater than rice and wheat. The proper utilization of bamboo seeds, as potential non-timber forest produce can be boon for ecological and economical sustenance [3]. Recently, a series of studies (very few) has been initiated on the bamboo seed and its characterization to elucidate the factors involved in dictating the quality of bamboo seed and to exploit the possible usage of bamboo seed in other processed food products. But the detailed information on pasting properties of bamboo seed is yet to be explored and still there is a need to exploit the exact protocol for pasting property determination using Rapid Visco Analyser (RVA) [4]. Hence the present study aimed to determine the optimum flour concentration, starting and ending temperature range of pasting profile and shear rate for the determination of pasting properties of bamboo seed flour.

## 2. Materials and Methods

### 2.1 Materials

Bamboo rice is an all-natural, short-grain with a slight jasmine green tea taste and a gorgeous jade green color. The Asian people hangs this rice over a bamboo pole to dry and then shifts it through a bamboo sieve and carries it home in a bamboo basket. The bamboo seed of three months old was procured from Department of Forest Service at Salem, ground into flour, packed in airtight container and used for analysis by RVA.

### 2.2 Profile Optimization

The starting point for performing any RVA analysis is to decide the sequence of paddle rotation speed and temperature at which the samples are subjected. The sequence is called a "profile". It comprises a series of timed (hours: minutes: seconds) targets for paddle speed (rpm) and temperature (°C). Several profiles that will suit a wide variety of applications are supplied with the Thermocline for Windows (TCW) software. Profiles may be created from scratch or modified to fit a particular need. The standard 1 profile was used as a base for the determination of pasting properties of bamboo seed flour.

The Standard 1 profile comprised of a programmed heating and cooling cycle with initial temperature of 50˚C, holding for one minute, heating to the maximum temperature of 95˚C for 3.42 min, holding at 95˚C for 2.3 min, cooling to 50˚C for 3.48 min and holding at 50˚C for 2 min at the rotational speed of 160 rpm with 13 minutes of total test time [5]. The bamboo seed flour was passed through 60 mesh test sieve (BSS unit) prior to analysis.

### 2.3 Experimental Design for Optimization

The sample concentration (%), temperature (°C) and shear rate (rpm) were considered as independent variable and the level of independent variables was optimized using (RSM) Response Surface Methodology. The Central Composite Rotatable Design (CCRD) was used to determine the optimum level of independent variables. The experimental design in the coded and actual level of variables is shown in Table 1.

**Table 1.** Independent variables and their levels in central composite rotatable design

A. Level of Independent Variables

| Independent Variables | Symbols | Coded levels | | | | |
|---|---|---|---|---|---|---|
| | | -2 | -1 | 0 | 1 | 2 |
| Shear Rate (rpm) | A | 120 | 140 | 160 | 180 | 200 |
| Concentration (%) | B | 2 | 2.5 | 3 | 3.5 | 4 |
| Initial/Final Temperature (°C) | C | 30 | 40 | 50 | 60 | 70 |

B. Experimental Plan

| A | B | C | Number of experiments |
|---|---|---|---|
| ± 1 | ± 1 | ±1 | 8 |
| ± 2 | 0 | 0 | 2 |
| 0 | ±2 | 0 | 2 |
| 0 | 0 | ±2 | 2 |
| 0 | 0 | 0 | 6 |

### 2.4 Responses for Optimization

The RVA parameters such as Peak Viscosity (PV): the highest viscosity during heating; Trough Viscosity (TV): the lowest viscosity after peak; Breakdown Viscosity (BDV): peak viscosity minus trough viscosity; Final Viscosity (FV): the viscosity at the completion of the cycle; Setback Viscosity (SBV): final viscosity minus peak viscosity; Peak Time (PT): time at which the peak viscosity occurred; Pasting Temperature (PTe): temperature at which viscosity started increasing were considered as responses for optimization.

### 2.5 Point Prediction and Numerical Optimization

A second order quadratic polynomial regression equation model was fitted to the data of all responses for prediction. The proposed model was:

Where, $\beta_0$, $\beta_1$, $\beta_2$, $\beta_3$, $\beta_{11}$, $\beta_{22}$, $\beta_{33}$, $\beta_{12}$, $\beta_{13}$, $\beta_{23}$ were the regression coefficients; A, B and C were the independent variables and Y was the dependent variable. The interactive effect of independent variables on the responses was determined using contour plots, 3D surface and cubical graph [6].

Numerical optimization was adopted to determine the optimum level of each independent variable. According to reference [7], the maximum peak vis-

**Table 2.** Estimated response levels for experimental runs

| Runs | PV (cP) | TV (cP) | BDV (cP) | FV (cP) | SBV (cP) | PT (min) | PTe (°C) |
|---|---|---|---|---|---|---|---|
| 1 | 672.5±67.1 | 392±42.42 | 280.5±24.7 | 869.5±31.8 | 477.5±10.6 | 5.33±0.0 | 63.33±18.6 |
| 2 | 448.5±61.5 | 288.5±36.1 | 160±25.45 | 622±66.46 | 333.5±30 | 5.3±0.04 | 89.85±0.70 |
| 3 | 2619 ±18.4 | 1419±93.3 | 1200±111.7 | 3137.5±19.09 | 1718.5±112.4 | 5.4±0.0 | 76.55±0.07 |
| 4 | 2067.5±62.93 | 1051.5±50.20 | 1016±113.1 | 2521±110.30 | 1469.5±160.5 | 5.265±0.09 | 63.425±15.87 |
| 5 | 596±28.28 | 350.5±16.26 | 245.5±12.0 | 597±4.24 | 246.5±12.02 | 5.1±0.14 | 75.3±16.61 |
| 6 | 324±57.98 | 244±33.941 | 80±24.04 | 400.5±58.68 | 156.5±24.74 | 5.035±0.04 | 91.75±1.34 |
| 7 | 1846±9.89 | 1044.5±70.00 | 801.5±24.0 | 1833±29.69 | 788.5±99.70 | 5.1±0.14 | 76.625±1.37 |
| 8 | 1460.5±62.93 | 862±12.72 | 598.5±50.2 | 1473.5±38.89 | 611.5±26.16 | 5.1±0.04 | 77.625±0.88 |
| 9 | 978.5±34.64 | 643.5±6.36 | 335±28.28 | 1241±36.76 | 597.5±30.40 | 5.4±0 | 86.35±0.07 |
| 10 | 733.5±24.74 | 484.5±34.64 | 249±9.89 | 943.5±33.23 | 459±1.41 | 5.2±0.09 | 81.95±7.49 |
| 11 | 192±1.41 | 149±1.41 | 43±2.83 | 266.5±2.12 | 117.5±0.70 | 5.13±0.0 | 48.3±0.21 |
| 12 | 2793±22.62 | 1564±32.52 | 1229±55.15 | 3057.5±24.74 | 1493.5±7.77 | 5.2±0.09 | 71.825±4.49 |
| 13 | 1118.5±3.53 | 651.5±10.60 | 467±7.07 | 1657.5±86.97 | 1006±76.36 | 5.765±0.04 | 69.175±14.38 |
| 14 | 840±43.84 | 495±24.04 | 345±67.88 | 695±2.82 | 200±21.21 | 4.9±0.04 | 83.975±2.43 |
| 15 | 1111±12.72 | 650.5±12.02 | 460.5±0.70 | 1357±5.65 | 706.5±17.67 | 5.27±0.0 | 63.5±16.33 |
| 16 | 1195±4.2 | 668.5±12.02 | 526.5±16.3 | 1409.5±0.70 | 741±12.72 | 5.235±0.04 | 79.5±1.69 |
| 17 | 1129.5±16.2 | 657±11.31 | 472.5±4.94 | 1336±11.31 | 679±0.0 | 5.3±0.042 | 79.025±0.03 |
| 18 | 993±14.14 | 590.5±33.23 | 402.5±47.4 | 1189.5±24.74 | 599±57.98 | 5.27±0.0 | 82.3±3.46 |
| 19 | 1153±11.31 | 659±9.89 | 494±1.41 | 1388±2.82 | 729±7.07 | 5.27±0.0 | 79.125±0.03 |
| 20 | 1026.5±31.81 | 658±22.62 | 368.5±9.19 | 1520±432.74 | 612±56.56 | 5.335±0.09 | 70.575±6.32 |

Values are the average of three determinants.

**Table 3.** Regression coefficients for estimated responses

| Coefficient | PV | TV | BDV | FV | SBV | PT (min) | PTe (°C) |
|---|---|---|---|---|---|---|---|
| $\beta_0$ | 1128.057 | 655.6591 | 472.3977 | 1386.2 | 690.8295 | 76.16023 | 5.268068 |
| $\beta_1$ | -120.188 ** | -67.375* | -52.8125* | -125.938** | -58.4063** | 1.378125 | -0.03938 |
| $\beta_2$ | 697.125* | 370.75* | 326.375** | 753.625* | 382.7188* | 1.315625 | 0.015 |
| $\beta_3$ | -133.625** | -60.1875* | -73.4375 | -298.188* | -237.844* | 3.609375* | -0.16813 |
| $\beta_{12}$ | -55.125 | -42.5 | -12.625 | -66.5 | -24.3125 | -6.8875 | -0.005 |
| $\beta_{13}$ | 14.75 | 22.75** | -8.0 | 38.5 | 16.0625 | 0.50625 | 0.0125 |
| $\beta_{23}$ | -147.37** | -59.75** | -87.625** | -232.25* | -172.813* | 0.05 | 0.00375 |
| $\beta_{11}$ | -47.9716 | -16.608 | -31.3636 | -58.8352 | -30.8352 | 2.364489 | -0.00097 |
| $\beta_{22}$ | 111.1534* | 56.51705* | 54.63636** | 83.6023** | 38.47727 | -3.65739 | -0.03472 |
| $\beta_{33}$ | -17.1591 | -14.2955 | -2.86364 | -37.8352 | -12.1477 | 0.470739 | 0.007159 |
| $R^2$ | 0.941 | 0.969 | 0.893 | 0.800 | 0.952 | 0.266 | 0.782 |
| Model ‘p’ value | < 0.0001 | < 0.0001 | < 0.0001 | 0.0008 | < 0.0001 | 0.1944 | 0.0012 |
| Adequate precision | 23.32 | 32.47 | 16.78 | 26.47 | 22.24 | 4.68 | 11.61 |
| CV % | 14.52 | 9.55 | 22.51 | 28.22 | 14.16 | 11.79 | 1.56 |
| Lack of fit ‘p’ value | 0.0168 | 0.0142 | 0.0353 | 0.0020 | 0.0685 | 0.2178 | 0.0106 |

** Significant at 5% level, * Significant at 1% level

**Table 4.** Regression equation for estimated responses in actual terms

| Responses | Regression Equation |
|---|---|
| Peak viscosity | $-7399.95+45.22*S+1082.32*F+80.421*ST-5.5125*S*F+0.07*S*ST-29.48*F*ST-0.1199*S^2+444.61*F^2-0.17*ST^2$ |
| Trough viscosity | $-3037.08+16.98*S+662.590*F+25.93*ST-4.25*S*F+0.114*S*ST-11.95*F*ST-0.042*S^2+226.07*F^2- S^2 0.143*ST^2$ |
| Breakdown viscosity | $-4362.82+28.24*S+491.73*F+54.49*ST-1.26*S*F-0.04*S*ST-17.53*F*ST-0.078* S^2 +218.5* F^2 0.029* ST^2$ |
| Final viscosity | $-10958.261+51.096*S+2887.30*F+116.57*ST-6.65*S*F+0.1925*S*ST-46.45*F*ST-0.147*S^2+334.4*S^2+3334.4*F^2-0.378*ST^2$ |
| Setback viscosity | $-6549.86+25.03*S+1959.11*F+79.2*ST-2.43*S*F+0.08*S*ST-34.5625F*ST-0.08* S^{2+153.91*} F^2 -0.12* ST^2$ |
| Peak Time | $5.57357955-0.002821*S+0.90568182*F-0.0362216*ST-0.0005*S*F+0.00006-05*S*ST+0.00075*F*ST-0.00002*S^2-0.1388636*F^{2+0.00007*} ST^2$ |
| Pasting Temperature | $-238.23+0.117*S+200.1*F-0.545*ST-0.689*S*F +0.003*S*ST +0.01*F*ST +0.006*S^2 -14.623*F^2+0.005*ST^2$ |

A-Speed, B-Flour, C-Starting Temperature

**Table 5.** Optimum profile conditions for RVA test procedures

| Solution No. | Shear rate(rpm) | Flour concentration(g) | Initial and Final temperature ($^0$C) |
|---|---|---|---|
| 1 | 121.1 | 3.9 | 34.9 |
| 2 | 123.1 | 3.9 | 32.3 |

**Table 6.** Optimum independent variables and its predicted and actual response levels

| S. No. | Responses | Predicted | | Actual | |
|---|---|---|---|---|---|
| | | Solution-1 | Solution-2 | Solution-1 | Solution-2 |
| 1 | Peak viscosity | 3660.05 | 3734.24 | 3399.3** | 3811 |
| 2 | Trough viscosity | 2044.88 | 2066.74 | 2380.67 | 2411 |
| 3 | Break down viscosity | 1615.17 | 1667.50 | 1250** | 1400 |
| 4 | Final viscosity | 4446.04 | 4595.74 | 4428 | 4882** |
| 5 | Setback viscosity | 2471.29 | 2604.30 | 2380.67 | 2471 |

$$Y = \beta_0 + \beta\ Y = \beta_0 + \beta_1 A + \beta A + \beta_2 B + \beta B + \beta_3 C + \beta C + \beta_{12} AB + \beta AB + \beta_{13} AC + \beta AC + \beta_{23} BC + \beta BC + \beta_{11} AA + \beta AA + \beta_{22} BB + \beta BB + \beta_{33} CC\ CC$$

cosity and final viscosity was considered as set goal for optimization of independent variables which result in the best suited optimum profile for testing the pasting properties of bamboo seed flour.

## 2.6 Statistical Analysis

All responses were determined in triplicate and the average was considered for optimization. The experimental data were analyzed statistically using Design Expert Software 8.0.3.1 and SPSS version 17.0.

# 3. Results and Discussion

## 3.1 Estimated Response Levels

The RVA parameters were determined as responses for predicting optimum RVA test profile for bamboo seedflour and the estimated levels of each response for 20 experimental runs as per CCRD design matrices (Table 2) reveal that the maximum RVA pasting profile was noted in run 3 and run 12 suggesting 140 and 160 rpm as rotational speed of paddle, 40$^0$C and 50$^0$C as starting and ending temperature of profile and 3.5 and 4g as bamboo seed flour concentration respectively. The RVA pasting profile was very low in run 11 with 160 rpm as rotational speed of paddle, 50$^0$C as starting and ending temperature of profile and 2g as bamboo seed flour concentration. Thus the flour concentration plays a significant role in RVA pasting profile determination of bamboo seed flour.

## 3.2 Influence of Independent Variables on Response

The magnitude of the terms indicates the order of influ ence on each response and the difference in magnitude of the quadratic terms explains the response. The coefficients for the proposed second order quadratic polynomial

The magnitude of the terms indicates the order of influence on each response and the difference in magnitude of the quadratic terms explains the response. The coefficients for the proposed second order quadratic polynomial regression equation in terms of coded variables (Table 3) and the regression equation in terms of actual variables (Table 4) predict that at linear level, shear rate (rotational speed of paddle) negatively influenced the peak viscosity, trough viscosity, final viscosity and setback viscosity at $p<0.05$. The effect of flour concentration on peak viscosity, trough viscosity, breakdown viscosity, final viscosity and setback viscosity was positive and significant at $p<0.01$. The starting and ending temperature of RVA profile also revealed significant negative effect on all determined viscosity parameters at $p<0.05$. According to magnitude of terms, flour concentration revealed greater influence on RVA viscosity parameters. At interactive level, flour concentration and temperature revealed significant negative effect on peak viscosity, trough viscosity, breakdown viscosity and setback viscosity at $p<0.05$ (Figure 1a–d). The concentration, time, shear rate, temperature, particle size, evaporation and cavitations are the factors influencing the pasting properties of rice starch [8]. Changes in time, temperature and chemical levels significantly changes peak, hot paste and final viscosities [9]. Accordingly shear rate, flour concentration and temperature revealed significant effect on pasting properties of bamboo seed flour.

The adjusted $R^2$ value $\geq 0.8$ for responses such as peak viscosity, trough viscosity, breakdown viscosity, final viscosity and setback viscosity revealed good fit of the model for these determined responses. While considering the general rule, the Coefficient of Variation (CV %) <10% for trough viscosity suggested the experiment conducted were precise and reliable. Adequate Precision measures the signal to noise ratio. Adequate precision >4 is desirable; the Adequate Precision value >4 for all determined RVA parameters excluding peak time indicated adequate signals for better prediction and optimization. According to the significance of model ($p<0.01$) for all determined RVA parameters excluding peak time, the proposed second order quadratic polynomial regression equation model was adequate to describe the experimental data. The lack of fit 'p' value was significant at $p<0.05$ for all determined parameters excluding peak time indicated the bad lack of fit which could occur due to noise.

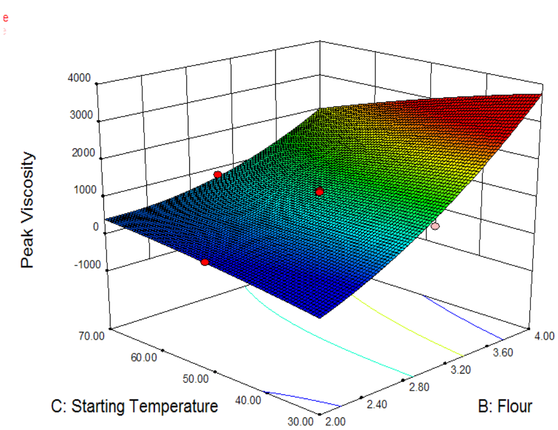
## 3.3 Optimisation and Validation

Numerical data optimisation was adopted to determine the optimum level of each independent variable. The optimum profile conditions for RVA test procedures for bamboo seed flour was determined as per the set goals for peak viscosity and final viscosity with maximum desirability function of 1.000.

Totally two optimum profile conditions (Table 5) were selected according to the maximum peak and final viscosity. The predicted levels of responses for each optimum profile conditions of independent variables were validated through one sample 't' test (Table 6); significant difference between predicted and actual value was noted for peak viscosity and breakdown viscosity in solution no.1 (Table 5); Final viscosity in solution no.2 (Table 5) at $p<0.01$. While considering the maximum peak and final viscosity as set goal, solution no.2 was selected as optimum profile conditions for the determination of pasting properties of bamboo seed flour using RVA. The optimised bamboo seed flour concentration (3.9 g) was greater than the concentration (3 g rice flour mixed with 25 ml of distilled water) suggested by [10].

# 4. Conclusion

The flour concentration had significant effect on RVA viscosity parameters. On the basis of maximum peak and final viscosity, 123 rpm as rotational speed of paddle, 3.9g as flour concentration mixed in 25 ml of water (15.6%) and 32.3oC as starting and ending temperature in standard 1 profile of RVA test procedure was considered as optimum profile conditions for the determination of pasting properties of bamboo seed flour.



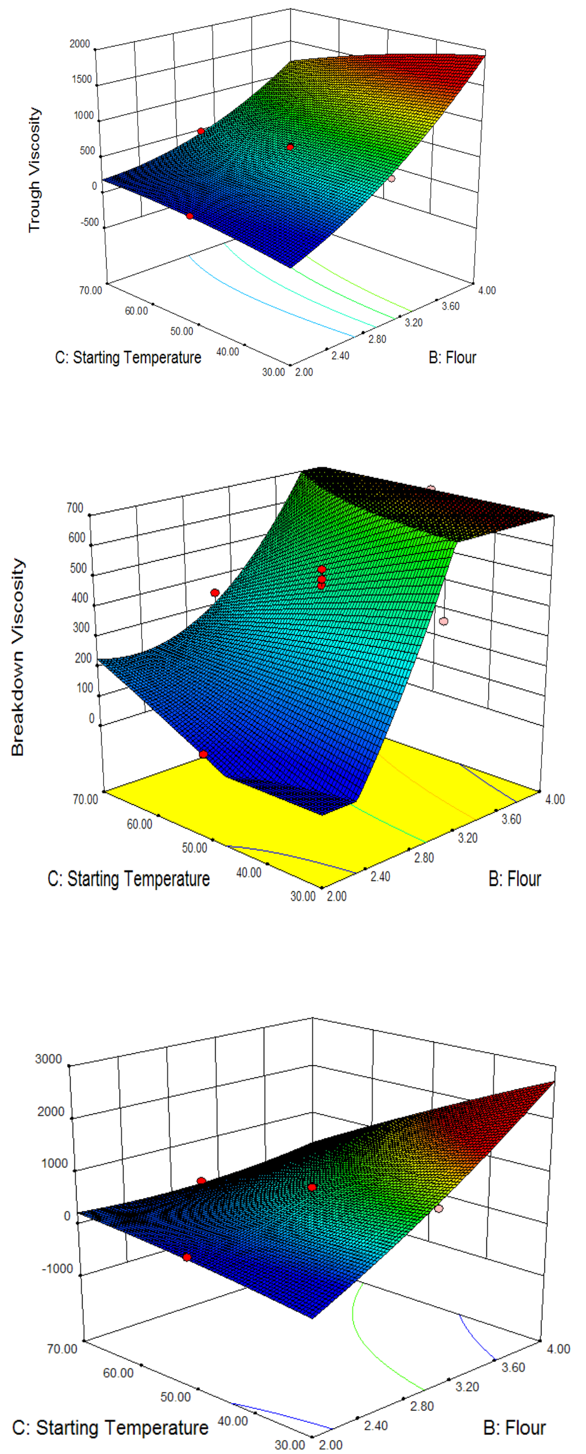



**Figure 1(a-d).** Shows the significant interactive effect of independent variables on responses (a-Peak viscosity, b-Trough viscosity, c-Breakdown viscosity, d-Setback viscosity).

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