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Market Dynamics of ByadagiChilli: Analyzing Price Trends and Growth Patterns

Mangala C. Devihosoor[1*], Ashalatha K.V.[1], Basavaraj A.A.[1], Huchesh Budihal[1], Ashwini C. B.[1], Vikas Jain[2], Roshan K. Bhardwaj[3], Hamsa K.R[4]. Lakshmi Narsimhaiah[5] and R.P. Joshi[6]

[1]*Department of Agricultural Statistics, UAS(Dharwad), Karnataka, India*
[2]*College of Agriculture, J.N.K.V.V., Powarkheda, M. P., India*
[3]*College of Agriculture and Research Station, Korba, Chhattisgarh, India*
[4]*College of Agriculture and Research Station, Kurud, Chhattisgarh, India*
[5]*College of Agriculture and Research Station, Jashpur, Chhattisgarh, India*
6College of Agriculture, J.N.K.V.V., Rewa, M. P., India
**Corresponding author E-mail: mangalad39@gmail.com*

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Abstract: This study investigates the growth patterns and price trends of Byadagi chilli in the Indian spice market from 2000 to 2022, emphasizing the application of Compound Annual Growth Rate (CAGR) and trend analysis. Byadagi chilli, distinguished by its vivid red hue, wrinkled texture, and mild spiciness, is a highly valued spice with economic significance, holding a Geographical Indication (GI) tag for authenticity. Using month-wise price data, we analyzed growth and long-term trends in prices through regression models. The CAGR results indicate a steady annual growth of 4.62% from 2000 to 2011, which accelerated to 11.34% from 2012 to 2022, yielding an overall CAGR of 7.17%. This shift suggests enhanced growth due to favorable market conditions and strategic initiatives. Trend analysis using polynomial regression models showed that the third-degree polynomial provided the best fit with the lowest RMSE (1805.13), effectively capturing the relationship between time and price, while higher degrees risked overfitting. The findings highlight Byadagi chillies expanding economic impact and provide insights into pricing trends, supporting future strategies for market stakeholders.

Keywords: Market Dynamics, CAGR, GI, RMSE.

Introduction

Byadagi chilli, a renowned variety of red chilli from Byadagi in the Haveri district of Karnataka, India, is widely valued for its vibrant color, rich flavor, and distinctive aroma. Unlike many other chilli varieties, it is characterized by mild spiciness, a wrinkled texture,

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and a high content of capsanthin, a natural coloring agent responsible for its deep red hue. These attributes make Byadagi chilli a preferred choice in spice blends, sauces, pickles, and masalas, where it enhances both color and flavor without excessive heat. Beyond its culinary appeal, Byadagi chilli holds significant economic value, particularly in the production of paprika and natural food coloring. Its Geographical Indication (GI) tag ensures authenticity and protects its market identity. With rising demand in the Indian spice market, analyzing its price trends and growth patterns is crucial for understanding market fluctuations and future potential.

In the fields of finance, investment, and business strategy, Compound Annual Growth Rate (CAGR) and Trend Analysis are two fundamental concepts used to evaluate growth and forecast future performance. These tools are crucial for investors, analysts, and business owners in assessing long-term investments and market dynamics.

CAGR, a widely used financial metric, represents the average annual growth rate of an investment or market variable over a specific period, assuming steady growth. It eliminates short-term fluctuations and provides a clear, long-term perspective on growth, making it useful for comparing different markets, commodities, or businesses. Similarly, Trend Analysis involves examining historical data to identify patterns, cycles, and anomalies. Using methods such as linear regression, moving averages, and polynomial trend models, it helps businesses forecast future trends and make informed decisions.

Several studies have examined price trends and market arrivals of agricultural commodities using CAGR and trend analysis. Saha and Kumar (2020) analyzed onion prices and market arrivals across major Indian markets, studying seasonal patterns and price variability from 2009 to 2019. Their findings indicated positive linear trends in arrivals but negative trends in real prices, except in Bangalore (-5.50/q per annum). The Compound Annual Growth Rate (CAGR) for arrivals was positive, whereas real prices showed negative growth in most months.Dhende et al. (2020) examined agricultural commodity trends at APMC, Sangli, from 2007 to 2018, revealing significant increases in the arrivals of gram, turmeric, and raisins, while soybean arrivals declined. Prices for all commodities exhibited a consistent upward trend throughout the study period.

By applying similar methodologies to Byadagi chilli, this study aims to provide a comprehensive analysis of its market performance, examining price trends, growth rates, and influencing factors over the past two decades.

Materials and Methods

The material and method for this objective were adapted from books, *viz.*, Applied Regression Analysis (1998) by Norman R Draper and Smith H and Fundamentals of Applied Statistics (1978) by Gupta S C and Kapoor V K.The study was based on secondary data. Month-wise price data was collected from 2000 to 2022 from Online Agricultural Marketing Information System, Department of Agricultural Marketing and Karnataka State Agricultural Marketing Board, Government of Karnataka.

Compound Annual Growth Rate (CAGR)

To compute average compound growth rates of price, the following form of regression equation was used.

$$Y_t = ab^t e^u$$

where,

Y_t = dependent variable (Price),

a = intercept term,

b = (1 + r) and r is the compound growth rate,

t = time (t = 1, 2, 3...n. annual price),

u = error term.

The above exponential equation can be expressed in terms of log form as follows:

$$\text{Log}Y = \text{Log}a + t\,\text{Log}b.$$

Now, CAGR per cent can be expressed as:

CAGR per cent = (Antilog b - 1) x 100.

Estimation of Linear and non-linear Trend (T_t)

For estimating the long-run trend of prices, the method of least squares estimate was employed. This method of ascertaining the trend in a series of annual prices involves estimating the co-efficient of intercept (β_0) and slope (β_i) in the functional form. The equation adopted for this purpose was specified as follows.

1. **Linear model:** The simple linear regression model for n observations can be written as

$$Y = \beta_0 + \beta_1 X_1 + \varepsilon.$$

Where,

Y = Dependent variable (monthly price),

X = Independent variable (Time),

β_0 = Intercept,

β_1 = coefficient to be estimated,

ε = error.

2. **Quadratic model**: Here the model is

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \varepsilon.$$

Where,

Y = Dependent variable (monthly price),

X = Independent variable (Time),

β_0 = Intercept,

β_1, β_2 = coefficients to be estimated,

ε = error.

3. Cubic model: Here model is

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \varepsilon.$$

Where,

Y = Dependent variable (monthly price),

X = Independent variable (Time),

β_0 = Intercept,

β_1, β_2, β_3 = coefficients to be estimated,

ε = error.

4. Polynomial model: Here model is

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \beta_4 X^4 + \varepsilon$$

Where,

Y = Dependent variable (monthly price),

X = Independent variable (Time),

$\beta_{0\,=}$ Intercept,

β_1, β_2, β_3, β_4 = coefficients to be estimated,

ε = error.

Estimating a trend line is to extract a trend from the data, the changes caused by broad secular forces.

Result

Descriptive statistics of the price of dry chilli

A comprehensive statistical summary of the dataset across multiple years, including metrics like range, minimum, maximum, mean, standard deviation, coefficient of variance, skewness, and kurtosis are presented in Table 1. The average prices show an upward trend over time, going from 3,804 to 19,868. The mean price dropped to ₹3,743 in 2005, which is one of the lower points. The year 2011 saw a significant increase in the mean price of dry chilli compared to the preceding years. The mean price of 2016 surged to 10,429, marking a notable increase. The year 2016 saw a substantial price range, with a standard deviation of 1,481. Another peak in the mean price occurred in 2020, reaching 18,515. The highest mean price recorded in the dataset is 19,868, suggesting a substantial range in prices.The overall skewness of the dataset is 1.440, indicating that, on average, the data across these years is moderately right-skewed. The overall kurtosis is 1.660, which is less than 3, indicating a generally platykurtic distribution across the dataset.

Table 1: Descriptive Statistics for the price of dry chilli in the Byadagi market, Haveri district

Year	*Range*	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*	*CV*	*Skewness*	*Kurtosis*
2000	1600	3000	4600	**3804**	401	10.53	0.027	1.235
2001	594.0	3684	4278	3977	158	3.97	0.174	0.823
2002	1111	3567	4678	4109	433	10.55	0.029	-1.935
2003	1893	3827	5720	4701	511	10.88	0.235	0.289
2004	1433	5187	6620	5727	496	8.67	0.828	-0.549
2005	2842	2722	5564	**3743**	888	23.73	0.875	-0.198
2006	1317	4557	5874	5028	357	7.10	1.171	1.749
2007	770.0	4543	5312	4897	233	4.76	0.502	-0.633
2008	1050	5019	6069	5476	299	5.48	0.685	-0.014
2009	2150	5009	7159	5962	650	10.90	0.223	-0.695
2010	2293	4569	6862	5551	712	12.83	0.913	0.213
2011	1456	6269	7725	6620	404	5.76	-0.314	0.123
2012	2883	4704	75869	6496	971	17.66	1.311	0.435
2013	4970	4523	9493	6864	1361	19.83	0.266	0.168
2014	1865	7985	9850	8854	471	5.32	0.239	1.222
2015	1670	7987	9656	8859	543	6.12	-0.017	-1.311
2016	5550	9280	14829	**10429**	**1481**	16.05	2.762	4.388
2017	5794	8779	14572	11434	2123	23.02	0.093	-1.731
2018	3098	11503	14601	12496	922	10.00	1.346	1.494
2019	2766	9357	12123	10346	973	10.55	1.015	-0.460
2020	9213	12125	21338	**18515**	2610	28.29	-1.455	2.527
2021	7888	10073	17961	13442	2234	24.22	0.594	0.202
2022	8749	15280	24029	**19868**	3258	35.33	0.072	-1.746
Overall	21307	2722	24029	8113	4607	56.78	**1.440**	**1.660**

Compound Annual Growth Rate (CAGR)

From 2000 to 2022, the Compound Annual Growth Rate (CAGR) of dry chilli price was calculated by fitting an exponential equation to the data. The CAGR of Byadagi market dry chilli prices during period I was 4.62, for period II was 11.34 and finally, the overall 7.17%, indicating that the market prices have increased at an average annual rate of 7.17(%). Table 2 shows the CAGR in per cent.

Table 2: Compound Annual Growth Rate (CAGR) of prices of dry chilli

	CAGR		
	Period I	*Period II*	*Overall*
Year	2000 to 2011	2012 to 2022	2000 to 2022
CAGR (%)	4.62*	11.34**	7.17**

(*Note*: * and ** indicates significance at 5 and 1 per cent, respectively)

Trend analysis for dry chilli prices of the Byadagi market

The study of trends enables us to indicate the general direction of prices in the market. The data on the nature of trend movement in the prices of chilli in the Byadagi market showed that the third-degree polynomial equation was the best fit with the lowest RMSE (1805.13) values. The results are presented in Table 3. Graphically shown in Figure 1.

Table 3: Different degrees of polynomial for dry chilli prices of the Byadagi market

Degrees	*Equations*	*RMSE*
1st	$y = 48.897x + 1340.5$	2452.15
2nd	$y = 0.2808x^2 - 28.88x + 4944.2$	1861.65
3rd	$y = 0.0012x^3 - 0.2062x^2 + 25.174x + 3685.2$	1805.13
4th	$y = 0.000002x^4 + 0.0003x^3 - 0.0469x^2 + 15.328x + 3823.8$	1807.89

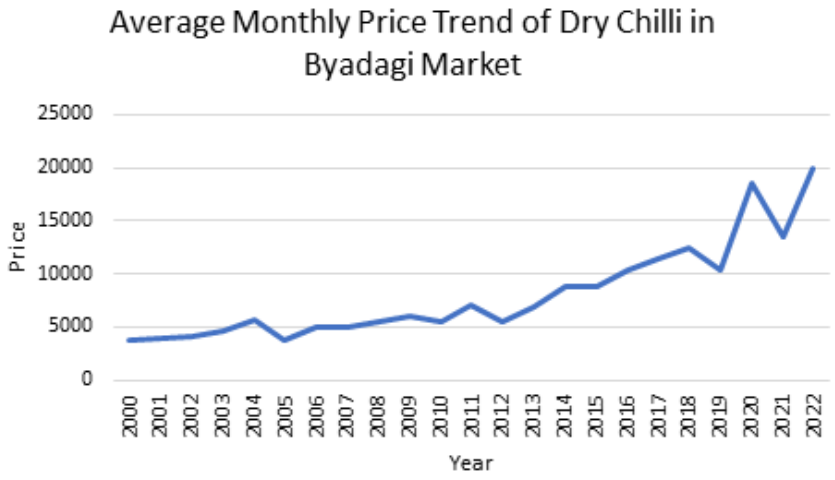

Figure 1: Trends in prices of dry chilli in the Byadagi market (2000-2022)

Discussion

The data in Table 1 indicates that average prices have generally trended upward, rising from 3,804 to 19,868, reflecting a broad increase in the price of dry chilli over time. However, there was a dip in 2005, primarily due to unusually heavy rainfall in Karnataka. In that year, rainfall reached 1,457.30 mm, significantly above the normal level of 1,165.00 mm, with a deviation of 430.59 mm, or 41.59 per cent. Similar results were found by Lokesh and Poddar (2018). A notable price increase occurred in 2011, driven by technological advancements in Karnataka's APMC. The number of bids per lot increased from approximately six to eleven, reducing the chances of collusion and encouraging greater competition among traders. From 2011 to 2015, average prices rose by 128 per cent in e-markets, compared to an 88 per cent

rise in non-e-markets, as noted by Reddy (2017). Furthermore, the E-NAM initiative has played a significant role in enhancing the agricultural marketing sector and boosting farmer incomes. According to Kalimuthu (2022), E-NAM now covers 11 per cent of the country's wholesale markets.

Compound Annual Growth Rate (CAGR)

According to Table 2, the compound annual growth rate (CAGR) for the first period, spanning from 2000 to 2011, was 4.62 per cent. This relatively modest growth rate indicates that the entity experienced steady progress during this time. Various factors could have influenced this pace, such as economic conditions and market maturity. It's possible that during this period, the market was still in its developmental stage or faced challenges that constrained growth.

In the second period, from 2012 to 2022, there was a notable increase in growth, with the CAGR rising to 11.34 per cent. This significant uptick suggests a phase of accelerated expansion, potentially driven by favourable economic conditions, market growth, technological advancements, or successful strategic initiatives. The more than doubling of the growth rate compared to the first period implies that the entity was able to overcome earlier challenges, seize new opportunities, or expand into new markets or segments.

Looking at the entire period from 2000 to 2022, the overall CAGR is 7.17(%). This rate represents a combination of the two distinct periods, reflecting both the steady growth in the early years and the rapid expansion in the later years. The overall CAGR points to a strong long-term growth trajectory, with the latter period significantly enhancing the overall performance. These findings align with the results reported by Kolageri and Bankar (2018).

Trend for dry chilli prices of the Byadagi market

The trends are the changes over the years and are associated with changes in technology of production, input supply, infrastructure, etc. From Table 3,it could be seen thatthe degree of the polynomial increases, the model's flexibility is enhanced, resulting in a lower RMSE for the 3rd-degree model. The 3rd-degree model best fits with the lowest RMSE of 1805.13, suggesting it effectively captures the true relationship between time and price. However, the slightly higher RMSE (1807.89) in the 4th-degree model indicates that further increasing the polynomial degree could lead to overfitting, trend was visually represented in Figure 1 for the overall period. Shashikumar (2014) also observed an upward trend in the prices of dry chilli.

Conclusion

The price data shows a general upward trend in dry chilli prices, increasing from 3,804 to 19,868 over time. A significant dip occurred in 2005 due to heavy rainfall in Karnataka, with rainfall reaching 1,457.30 mm, 41.59(%) above normal. A notable price surge happened in 2011, attributed to technological improvements in Karnataka's APMC, which increased

competition among traders. From 2011 to 2015, prices in e-markets rose by 128(%), compared to an 88% rise in non-e-markets. The E-NAM initiative has also been instrumental in enhancing agricultural marketing and farmer incomes, now covering 11(%) of India's wholesale markets.

From 2000 to 2011, the compound annual growth rate (CAGR) was 4.62(%), indicating steadyprogress during the developmental phase. From 2012 to 2022, the CAGR increased significantly to 11.34(%), reflecting accelerated expansion likely due to favourable conditions and strategic initiatives. Over the entire period from 2000 to 2022, the overall CAGR was 7.17(%), combining steady early growth with rapid later expansion, pointing to a strong long-term growth trajectory.

As the polynomial degree increases, model flexibility improves, reducing RMSE. The 3rd-degree model achieved the best fit with the lowest RMSE of 1805.13, accurately capturing the relationship between time and price. The 4th-degree model, with a slightly higher RMSE of1807.89, suggested that further increasing the polynomial degree may lead to overfitting, capturing noise rather than the true trend.

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All authors contributed to the study's conception and design. Mangala C. Devihosoor M. Sc. (Agri) Student, carried out research, processing and analysis of research data and manuscript writing. Ashalatha KV was Involved in finalising and implementing the research program, technical guidance, and preparation of research work.

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