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Rheometry of Roselle (*Hibiscus sabdariffa* L.) Seed Oil

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ABSTRACT

The viscosity of Roselle seed oil was studied to investigate the flow consistency index (K) and flow behavior index (n) while subjecting the oil to a shear rate of 10-10,000 per second for 4 minutes modeled with SAS[15] software based on Ostwald-de Waele power law equation. The outcome of the analysis showed index properties of K and n as 0.029 and 2.068 respectively. The value of n (2.068) > 1; predicts a dilatancy a shear thickening behavior evident in the increased viscosity and decreased fluidity with increased shear rate. Dilatancy is a rare behavior in food material typical in sausage slurry, homogenized peanut butter, some types of honey and 40 % raw corn starch solution. The linoleic fatty was the major essential fatty acid found in the Roselle seed oil. These finding shows that Roselle seed oil possesses a huge industrial novel application.

Key words: *Roselle seed oil, Ostwald-de Waele, Dilatancy*

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is a plant found predominantly in the tropic belonging to the family malvaceae widely cultivated for its jute like fibre in India and the red calyces used for local beverage globally. Roselle calyces and petals of the flower are extensively used to improve herbal drinks, cold and warm beverages, as well as making jams and jellies[14,20]. The Roselle drink has been shown to be a good source of ascorbic acid (Vitamin C)[11] while the seeds of this crops from which edible oil could be extracted are being wasted in its production areas after the farmers might have taken the quantity needed for the next planting season for calyces production[3,7]. In some parts of Africa the seeds are reported to be used for its oil. The seeds are reported to be rich in proteins, dietary fiber, carbohydrate and oil[2,6,9,14]. It contain substantial amount of oil that resembles that of cotton seed[10] and a rich source of carotenoids[13]. A lot of preliminary investigations have been conducted on the physical and nutritional qualities of different parts of the Roselle plant; however, the nature and behavior of the oil have not been studied extensively.

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The nature of food raw materials is a critical constituent that affects its handling the choice of processing techniques to be adopted and its effects as additives in the conversion to finish product. Viscosity is one of such attributes that defines the material science of food. Rheology is the study of the flow of matter primarily in a liquid state but also as soft solids[17]. Different food raw materials exhibit unique rheological properties depending on their natural consistency and thus affecting its functionality in food product development, food product quality and shelf life.

The unique behavior of food materials can be simulated using the *power law* which expressed a functional relationship between two quantities on which the study of viscosity hinges on; a study on the rate of change of shear stress (units in Pascal) on shear rate (units per seconds). One of such power law model is the *Ostwald-de Waele* relationship. The power law fluids can be subdivided into three different types based on the value of their flow behavior index (n): Pseudoplastic ($n<1$) a shear thinning fluid, Newtonian fluid ($n=1$) and Dilatancy ($n>1$) a shear thickening fluid, less common[18].

An exhaustive literature search suggest little has been done to study the rheology of Roselle seeds oil, thus the objective of this study was to evaluate the numerical rheological behavior of Roselle seed oil in relation to its flow consistency index (K) and flow behavior index (n).

MATERIAL AND METHODS

Materials

Seeds of Roselle (*Hibiscus sabdariffa L*) were obtained from the vegetable markets in Ahmednagar District, Maharashtra State, India.

Sample preparation and Equipment

Roselle seeds were cleaned by washing to separate poor quality seeds, adhering dust particles, stones, plant debris and were dried carefully at ambient conditions to preserve its nutritive value, packed in a high density polyethylene bag and stored in a cool dry place until used. The laboratory scale hammer mill used in milling the seed samples and the Rheometer used for the study the viscosity behavior of the Roselle seed oil extract were available in the Department of Food Science and Technology and the instrumentation laboratory in Dr. Annasaheb Shinde College of Agricultural Engineering Department of Agricultural Process Engineering all in Mahatma Phule Agricultural University, Rahuri, Maharashtra State, India.

Methods

Oil Extraction

A modified cold extraction method was adopted. 200g of the cleaned Roselle seeds flour was transferred into a 500 mL Erlenmeyer beaker to which petroleum ether was poured in up to the 400 mL mark and swirled using a glass rod to mix, the beaker was tightly sealed using a polythene film to minimize loss of ether. The set up was kept overnight in a cool dry place. The ether-oil supernatant extract was then carefully decanted and the ether was recovered using a soxhlet set up at 20 ^{o}C) to obtain the clear oil extract.

Rheometry Determination

Viscosity of Roselle seed oil was estimated using a rheometer (Brookfield, Mode: R/S SST coaxial rheometer) mounted with CC3-40 spindle and coaxial cylinder with a separation of 1mm at shear rate 10 to 1000 sec^{-1}. The results obtained from the studies were modeled with SAS[15] (2002-2010) software based on Ostwald-de Waele Power law (Eq. 1).

$$\eta = K(\delta u/\delta y)^{\wedge}(n-1)$$

Fatty acid profile analysis

Fatty acid profile analysis of Roselle seeds oil extracts where analyzed by gas-liquid chromatography using flame ionization detector. The GC was outsourced.

Statistical Analysis

Statistical analysis were conducted using excel 2010 software[12], and modeled with SAS[15] software with significance level taken at $p<0.05$.

RESULTS AND DISCUSSION

The data obtained from rheometry studies was modeled with SAS[15] software based on Ostwald-de Waele Power law (Eq. 1) to ascertain the flow behavior index (n) and flow consistency index (K) of the Roselle seed oil. The equation represents an apparent or effective viscosity as a function of shear rate (S.I unit Pa.s). Where $\boldsymbol{\eta}$ is the viscosity, K is a material based and $\boldsymbol{\delta u/\delta y}$ is the applied shear rate[5]. The law was adopted owing to its simplicity for describing the behavior of the Roselle oil across a range of shear rates to which the coefficients were fitted. However, there are a number of models that better describes the entire flow behavior of shear dependent fluids, but they do so at the expense of simplicity. The result obtained described the Roselle seed oil behavior, permit mathematical predictions and correlate the experimental data. The values for K and n were estimated as 0.029 and 2.068 respectively suggesting a dilatants behavior as the n-value (flow behavior index) is greater than one. Dilatancy is rarely encountered behavior[18] making Roselle seed oil a potential raw material for novel industrial application. This behavior could possibly have occurred because the Roselle seed oil had crystallize under stress and behaved more like a solid than a solution like a colloidal suspension transition from a stable state to a state of flocculation[5]. This was evident from the results (Table 1) where viscosity increased and fluidity decreased respectively with increased shear rate.

The trend function in excel 2010 was also used to confirm the relationship between the shear stress (Pa) and shear rate (per seconds) outcomes of the rheological study on Roselle seed oil (Table 1). Trend is a powerful statistical tool in excel used to calculate the relationship between two variables and defines if they are linear or non-linear[21]. It is called a multiple cell ray function which returns a number in a linear trend; it returns all predicted value of the dependent variable (Shear stress) and states how far they are predicted off. The difference between observed and predicted values gives the residual values. The plot of the standardized residual values against shear rates (per second) proved as shown in a defined parabolic graph (Figure 1) confirmed a non-linear relationship between Shear stress (Pa) and shear rate (per second). The direct plot of shear stress versus shear rate gave a polynomial relationship in a fourth order with coefficient of correlation (R^2=0.999; Figure 2). There was a significant difference ($P<0.05$) in the treatments showing an increasing trend in viscosity with increasing shear rate (per second) (Figure 3).

The fatty acid profile of oil extracts of Roselle seed is given in Table 2, which showed substantial and significant ($p<0.05$) lipid contents. The ratio of saturated to unsaturated fatty acids in whole Roselle seed was approximately 1:3. The major fatty acids found for raw seed oil were linoleic acid (41.18) followed by oleic acid (31.22%), palmitic acid (21.45) and stearic acid (3.94%). The results obtained in these research findings are in close harmony with El-Adawy and Khalil[6]; Emmy *et al*[7]., and Cissouma *et al*[4]. The Roselle seed oil can be classified as belonging to linoleic-oleic category as the most abundant unsaturated fatty acids present, suggesting it beneficial use in lowering blood pressure and serum cholesterol[4,8,16,19].

Table 1: Effect of shear rate (sec^{-1}) and time (sec.) on the viscosity of Roselle seed oil

Time(sec)	Shear rate (sec^{-1})	Shear stress (Pa)	TREND	Residual value(Pa)	Standardized Residual value (Pa)	Apparent Viscosity (mPa.s)	Fluidity $(mPa.s)^{-1}$
2	10.010	0.000	-0.516	0.516	3.209	0.000	
6	36.910	0.666	0.686	-0.021	-0.128	18.030	0.0555
10	63.800	1.838	1.887	-0.049	-0.307	28.809	0.0347
14	90.700	2.975	3.089	-0.114	-0.710	32.800	0.0305
18	117.600	4.138	4.291	-0.153	-0.954	35.183	0.0284
22	144.500	5.358	5.492	-0.134	-0.836	37.080	0.0270
26	171.400	6.584	6.694	-0.110	-0.685	38.413	0.0260
30	198.300	7.791	7.896	-0.105	-0.655	39.286	0.0255
34	225.200	9.015	9.097	-0.082	-0.513	40.031	0.0250
38	252.100	10.245	10.299	-0.054	-0.337	40.639	0.0246
42	279.000	11.470	11.501	-0.031	-0.192	41.111	0.0243
46	305.900	12.720	12.702	0.018	0.109	41.582	0.0240
50	332.800	13.955	13.904	0.050	0.314	41.931	0.0238
54	359.700	15.160	15.106	0.054	0.337	42.146	0.0237
58	386.600	16.395	16.307	0.088	0.545	42.408	0.0236
60	400.000	17.035	16.906	0.129	0.803	42.588	0.0235
SE(±)	0.13	0.03					
CD at 5%	0.38	0.08					
CV (%)	0.24	1.28					

*Each value is an average of three determinations

Table 2: Fatty acid profile of Roselle seed oil

Fatty Acids (g/100g)	Roselle Seed Oil	
	Raw Seed Oil	Sprouted Seed Oil
Lauric acid (C12:0)	0.01	0.01
Myristic acid (C14:0)	0.20	0.20
Palmitic acid (C16:0)	21.45	21.41
Stearic acid (C18:0)	3.94	3.87
Arachidic acid (C20:0)	0.59	0.56
Eicosenoic acid (C20:0)	0.01	0.10
Behenic acid (C22:0)	0.25	0.25
Lignoceric acid (C24:0)	0.14	0.15
Total Saturated Fatty Acid	**26.2**	**26.55**
Palmitoleic acid (C16:1)	0.44	0.43
Oleic acid (C18:2n6c)	31.22	31.99
Linoleic acid (C18:2n6c)	41.18	40.07
Gamma linolenic acid (C18:2n6)	0.01	0.01
Alpha linolenic acid (C18:3n3)	0.27	0.52
Cis-11,14-eicosadienoic acid (C20:2)	0.01	0.01
Total Unsaturated Fatty Acid	**73.13**	**73.03**
Lipid Dietary Profile Ratio	**1: 2.79**	**1: 2.75**

*Results of triplicate determinations

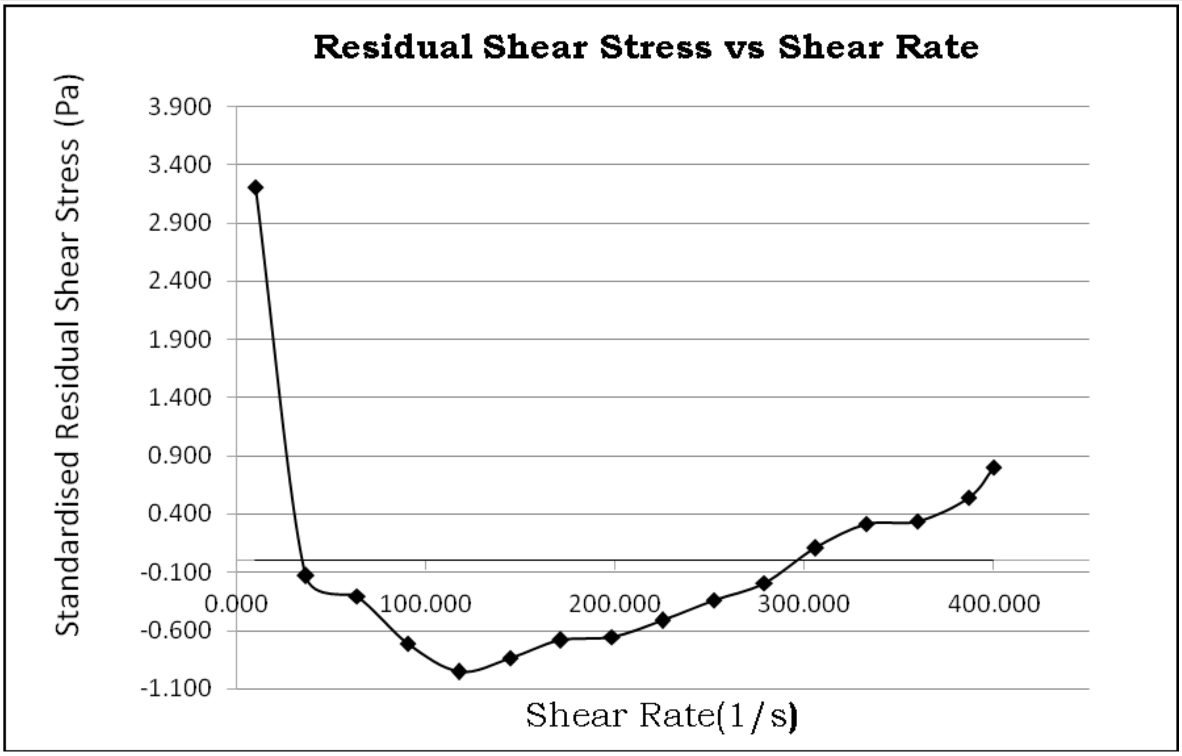

Fig. 1: Residual profile analyses of Roselle seed oil

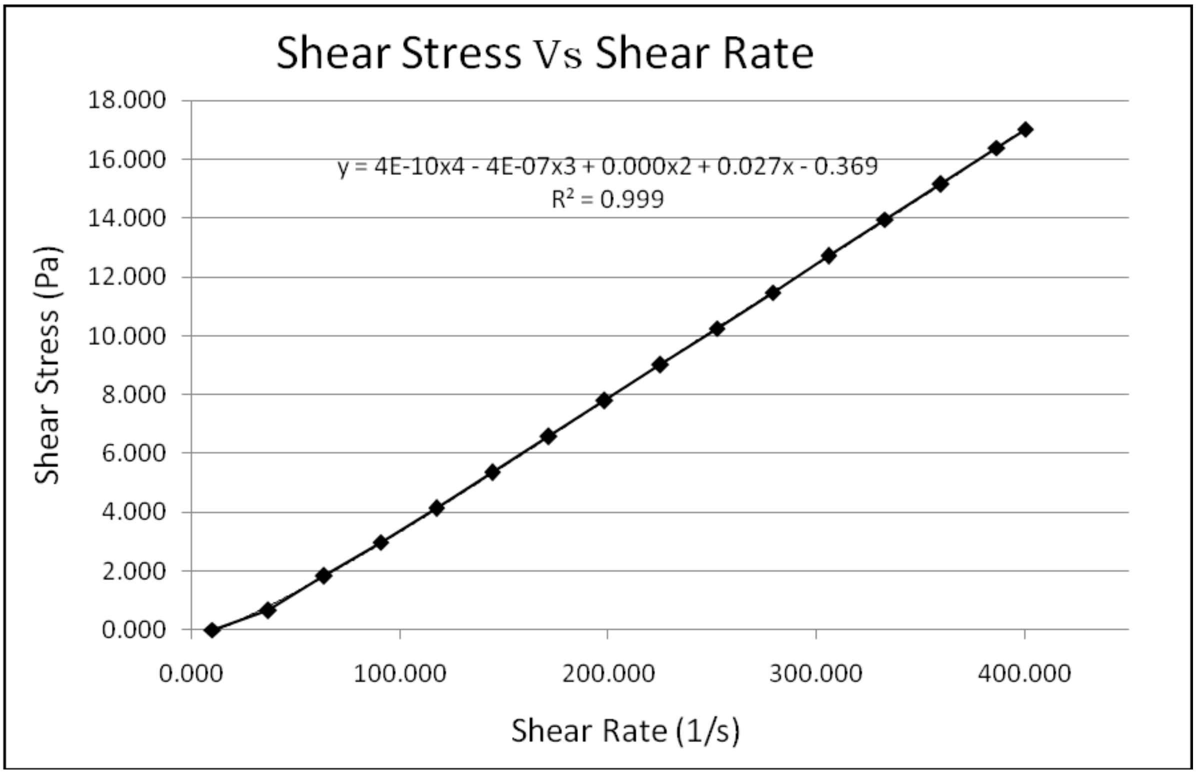

Fig. 2: Viscosity profile of Roselle seed oil

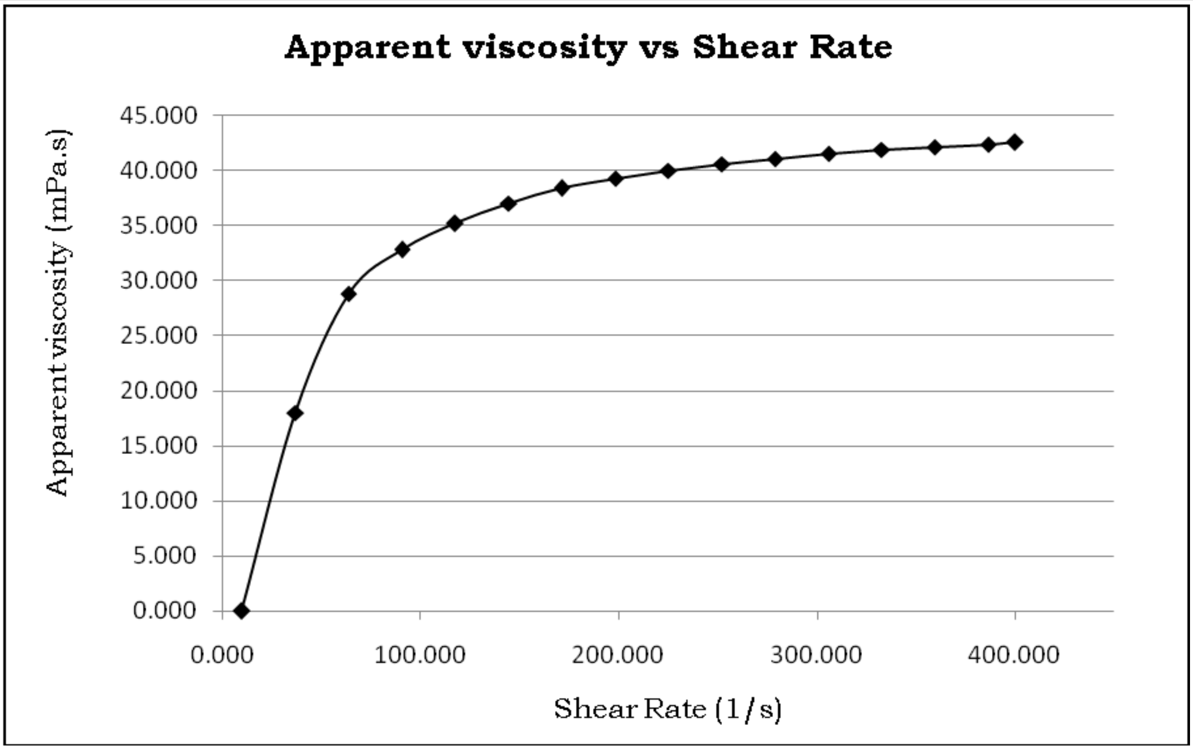

Fig. 3: Apparent viscosity profiles of Roselle seed oil

CONCLUSION

From the outcome of the rheometry studies, Roselle seed oil showed a shear thickening behavior, a case of *dilatancy* as shown by the upward trending curve a rare behavior among food ingredients. The fatty acid composition of Roselle seed oil showed very good essential oil profile. These findings suggest that Roselle seed oil could have a huge industrial application with enormous potential as a natural thickener in food processing, in the formulation of new products and as a lubricant also in medicine as a potential source of possible therapy for deficiency treatments of synovial fluids defects.

REFERENCES

1. AACC. Approved methods of the American Association of Cereal Chemists (10th ed.). St. Paul, MN: Author (method 46–13 for lipid content) (2000).
2. Abu-Tarboush, H.M., Ahmed, S.A.B. and Al Kahtani, H.A., Some nutritional properties of karkade (*Hibiscus sabdariffa*) seed products. *Cereal Chemistry*, **74:** 352-355 (1997).
3. Bambgoye, A.I. and Adejumo, O.I., Physical Properties of Roselle (*Hibiscus sabdariffa L.*) *Seed.* Agricultural Engineering International: the CIGR Ejournal. Manuscript 1154. **XI:** (2009).
4. Cissouma, A.I., Tounkara, F., Nikoo, Mehdi, Yang, N. and Xu, X., Phyico Chemical Properties and Antioxidant Activity of Roselle Seed Extracts. *Adv. J. Food Sci. Technol*., **5(11):** 1483-1489 (2013).
5. Coleman, P.C. and Painter, M.M., Fundamentals of Polymer Science: An Introductory Text (2nd ed.). Lancaster, Pa.: Technomic. 412-413 (1997).
6. El-Adawy, T.A. and Khalil, A.H., Characteristics of roselle seeds as a new source of protein and lipid. *Journal of Agricultural and Food Chemistry*, **42:** 1896-1900 (1994).
7. Emmy Hainida, K.I., Amin, I., Normah, H. and Mohd.-Esa, N., Nutritional and amino acid contents of differently treated Roselle (*Hibiscus sabdariffa L.*) seeds, *J. Food Chemistry*, **111:** 906-911 (2008).
8. Enujiugba, V.N. and Akanbi, C.T., Quality evaluation of canned fermented oil bean

seed slices during ambient storage. *Afr. J. Agric. Res*., **5(22):** 3096-3101 (2008).

9. Karma Bako Rimamcwe, and Chavan, U.D., Physical Properties and Nutritional Potentials of Indian Roselle (*Hibiscus sabdariffa L.)* Seeds, *International Journal of Current Research*, **8(09):** 38644-38648 (2016).
10. Mohammed, R., Fernendez, J., Pineda, M. and Aguilar, M., Roselle (*Hibiscus sabdariffa*) seed oil is a rich source of gamma tocopherol. *J. Food Sci*., **72:** 207-211 (2007).
11. Ogiehor, I.S. and Nwafor, O.E., Associated Microbial, Biochemical and Chemical Quality Changes in Sobo Beverage produced from *Hibiscus sabdariffa L. Niger. Ann. Natio. Sci*., **5(2):** 1-10 (2004).
12. Panse, V.G. and Sukhate, P.V., Statistical methods for Agricultural Workers. 4th ed., New Delhi (1985).
13. Ramadan, M.F. and Morsel, J.T., Oxidative stability of black cumin (*Nigella sativa L.*), coriander (*Coriandrum sativum L.*) and niger (*Guizotia abyssinica Cass.*) crude seeAd oils upon stripping. *Eur J Lipid Sci Technol*., **106:** 35-43 (2004).
14. Rao, P.U., Nutrient composition and biological evaluation of mesta (*Hibiscus sabdariffa*) seeds. *Plant Food for Human Nutrition,* **49:** 27-34 (1996).
15. SAS, SAS Institute Inc, Cary, NC, USA (2002-2010).
16. Savage, G.P., Chemical composition of walnuts (*Juglans regia* L.) grown in New Zealand. *Plants Food Hum. Nut*., **56:** 75-82 (2001).
17. Schowatter, W.R., Mechanics of Non-newtonian Fluids Pergamon. ISBN 0-08-021778-8 (1978).
18. Scott Blair, G.W., Hening, J.C. and Wagstaff, A., The Flow of Cream through Narrow Glass Tubes, *J. Phys. Chem*., **43(7):** 853-864 (1939).
19. Tounkara, F., Amadou, I., Le, G and Shi, Y., Effect of boiling on the physicochemical properties of Roselle seeds (*Hibiscus sabdariffa L.*) cultivated in Mali, *African J. of Biotechnology*, **10(79):** 181860-18166 (2011).
20. Tsai, P.J., Mc Intosh, J., Pearce, P., Camden, B. and Jordan, B.R., Anthocyanin and antioxidant capacity in Roselle (*Hibiscus sabdariffa L.*) extract. *Food Research International*, **35:** 351-356 (2002).
21. Vershuuren, Gerard, Excel 2007 for Scientist: A complete course for scientists and Engineers (Visual Training Series). ISBN – 10:1932802320. Online source: www.mrexcel.com (2007).