Vol. 51, n. 4 : pp.807-814, July-Aug 2008
ISSN 1516-8913 Printed in Brazil

BRAZILIAN ARCHIVES OF
BIOLOGY AND TECHNOLOGY
A N I N T E R N A T I O N A L J O U R N A L

Spray-Dried Tomato Powder: Reconstitution Properties and Colour

Alexandre Santos de Sousa[1], Soraia Vilela Borges[2]*, Natália Ferreira Magalhães[1], Hevandro Vaz Ricardo[1] and Aline Damico Azevedo[3]
[1]Departamento de Tecnologia de Alimentos; IT; Universidade Federal Rural do Rio de Janeiro; Km 47 da Antiga Rodovia Rio-SP; 23851-970; Seropédica - RJ – Brasil. [2]Departamento de Ciência dos Alimento; Universidade Federal de Lavras; sborges@ufla.br; 37200-000; Lavras - MG - Brasil. [3]Serviço Nacional de Aprendizagem Industrial; CETIQT; Rio de Janeiro - RJ - Brasil

ABSTRACT

Powdered tomato was produced by spray drying the tomato pulp. A full 2^3 factorial design with the central point was used, varying the feed flow rate (127-276 g/min), air inlet temperature (200-220^{o}C) and the atomisation speed (25,000-35,000 rpm). The responses analysed were: moisture content, solubility, wettability consistency and colour, but the factors only significantly affected the colour parameter. All the samples became significantly darker and less red with an increase of the variables under study. A low atomisation speed (25,000 rpm) and lower inlet air temperature (220^{o}C) produced the powders with a higher colour index (a/b) and less darkening.

Key words: spray dried tomato **(***Lycopersicon esculentum)*, colour, solubility, wettability

INTRODUCTION

The production of dry particles from a liquid feed in a single processing step makes the spray drying a unique and important unit operation. The design of a spray drying process includes the establishment of the operating conditions that increase the product recovery and produce an end product with a precise quality specification (Masters, 1991). The temperatures and drying conditions experienced by a droplet during the drying have an important influence on the powder properties (Masters, 1991). However, the effect of the process variables (e.g. the residence time of particles within the drying chamber, the atomisation conditions, the drying air temperature) on the powder properties are difficult to assess in general terms (Walton, 2000). This is due to a lack of information in the literature and to the specific drying nature of most materials.

Consumer demand for high quality, minimally processed products has increased remarkably in recent years. Preferences have shifted towards the fresh, healthy and rich flavoured ready-to-eat foods with an enhanced shelf life. Tomato powders are often used as an ingredient in the foods such as sauces and soups. Several food technology studies have been carried out to optimise the processing and storage of the tomato products by preventing the heat and oxidative damage on the antioxidants (Shi and Le Maguer, 2000). On the other hand, a useful optimisation

* Author for correspondence

criterion requires a global approach that includes all the quality characteristics of the tomato products. Hence, it is necessary both to minimize the damage to the sensory and nutritional quality and to maximize the safety and shelf life of the products.

Tomatoes are one of the most widely used and versatile vegetable crops. They are consumed fresh and are also used to manufacture a wide range of processed products (Madhavi and Salunke, 1998).Tomatoes and tomato products are rich in health-related food components, as they are good sources of carotenoids (in particular, lycopene), ascorbic acid (vitamin C), vitamin E, folate, flavonoids and potassium (Leonardi et al., 2000). The main antioxidants in the tomatoes are the carotenoids, ascorbic acid and phenolic compounds (Giovanelli et al., 1999).

The colour of foods is one of the most important sensory attributes for the product acceptance. Lycopene is responsible for the red colour of the tomatoes (Nguyen and Schwartz, 1999) and can be degraded by the thermal processing. During the spray drying, this property can be affected by the air conditions (temperature, flow rate), feed conditions (enzyme inactivation, additives, feed rate), and atomisation speed, amongst other factors (Masters, 1991; Desobry et al., 1997; Cai and Corke, 2000). Kalil and Sial (1974) studied the effect of these aspects with respect to the spray drying of the mango juice, and showed that the atomisation speed (40,000-50,000 rpm) had little effect on the colour. Abadio et al. (2004) also found insignificant variation in the values for a* and b* of the powdered pineapple juice. Goula and Adamapoulos (2005b) showed that the loss of lycopene increased with increases in air inlet temperature.

According to Desobry et al. (1997), the conditions favouring a high surface/volume ratio or a larger number of smaller particles tend to favour the pigment oxidation. In the case of spray drying, these conditions are favoured by high temperatures and atomisation speeds (Masters, 1991). The instant properties (penetration, wetting, dispersibility, solubility) are influenced by the nature of the feed (solids content, viscosity and temperature), type of spray dryer, operational speed and pressure and air inlet and outlet temperatures (King et al. 1984; Hall and Iglesias, 1997; Nath and Sapthy, 1998). Increases in the atomisation speed resulted in a reduction in the particle size and air incorporation in the feed, resulting in the porous products with low apparent density (Pisecky, 1978), making re-hydration more difficult (Maia and Golgher, 1983). The solubility of the powder is associated with the moisture content and operational conditions of the dryer, increasing with decrease in the moisture content (Papadakis et al., 1998; Goula and Adamopoulos, 2005a). The main objective of this study was to determine the effects of the spray dryer operational conditions on the moisture content, solubility, consistency wettability and colour index.

MATERIAL AND METHODS

Tomato pulp (brand KARAMBI, Brazil) was blended with 10DE malt dextrin (10% dm) and SiO_2 (1% dm), and spray dried in a pilot scale spray dryer (home made / DTA, UFRRJ, Brazil). The drying chamber was 2.5 m in diameter, 1.40 m cylindrical height and a conical base. All the internal surfaces in the contact with the product were of stainless steel AISI 316. It was equipped with a control panel (control of the atomizer speed, blower velocity and air inlet temperatures), rotary atomiser and gas burner. The feed was sprayed by a rotary atomiser and the co-current air entrance was carried out by a blower. The constant operational conditions were: outlet air temperature: 90ºC; blower velocity: 30,000 rpm. The variables atomisation speed (AS), feed flow rate (Q) and inlet temperature (T) were studied according to a complete 2^3 factorial design, with three repetitions at the central point (Table 1). The powdered samples were filled into the low-density polyethylene pouches and stored at 10ºC until analysed. The results were submitted to an analysis of variance and the effect estimates (Barros Neto et al, 1995) using the statistical software STATISTICA 5.0.

The colour was measured in a spectrophotometer, (model CM-3600d, KONICA MINOLTA, NJ, USA), eight times for each sample. The CIE *L*a*b* colour space was used for the determination of the colour, with *L** representing the lightness (0- black to 100- white), +*a** the red direction, -*a** the green direction, +*b** the yellow direction, and -*b** the blue direction. The colour index was calculated from the relation of a/b. The solubility was determined by homogenisation, centrifugation and determination of the insoluble residue from the dissolution of 1g of the powdered juice in 10ml distilled water at 25°C, according to the methodology adopted by IAL (1977). The consistency was measured at 25°C using a consistometer (Alpári, 1976) and wettability was based on the time for immersion of the powdered product sprinkled on the surface of a liquid at 25°C (Bhandari et al., 1993). The moisture content (vacuum oven at 70°C) according to IAL (1977).

Table 1 - Experimental conditions of the factorial design.

Level	-1	0	+1
X1 (°C)	200	210	220
X2 (g/min)	127	201	276
X3 (rpm)	25000	30000	35000

RESULTS AND DISCUSSION

Tables 2 and 3 present the assay results and the evaluation of the effects of the variables studied on the reconstitution properties and colour parameters. The results showed that the levels of the variables under the study did not the influence the moisture content, solubility, wettability and consistency. The value for the moisture content varied from 4.00 to 6.8 g/100g (dry matter), higher than the values found by Al Asheh et al, 2003 (3-1%) for the tomato powder in other drying conditions. However, in general, it was reduced by the increase of the inlet air temperature and of the atomization speed (Masters, 1991; Al-Asheh et al., 2003; Adamopoulos, 2005).

The values for the solubility were from 17.65 to 26.73%, low values when compared to the powdered tropical fruits, which shown values varying from 44.6 to 57.59%, for the passion fruit juice (Jorge et al., 2003) and 81.56% for the pineapple juice (Abadio et al., 2004). Thus, the tomato powder was of limited solubility in the water due to a low sugar content as compared to most fruits, and because it was rich in the liposoluble substances such as the carotenoids. This property has inversely been correlated with the moisture content, as lower moisture content favours a fast solubilization (Papadakis et al., 1998). Such relationship was found by Al Asheh et al (2003) and Goula and Adamopoulos (2005a) in the dehydrating tomato pulp studies, using the referred process. In the conditions used in the present study, both the properties were kept constant, and no significant correlation was found. This property was also related to the effects of the drying conditions on the degradation of the nutritive value due to the time of exposure to high temperatures. Smaller particles produced by the high-speed atomisation tend a to reach the higher temperatures at the surface (Perez – Muñoz and Flores, 1997) and were therefore, more sensitive to thermal damage and the loss of solubility. In relation to the feed flow rate, the Asheh et al (2003) also observed a loss of the solubility with increasing flow rate, and credited this to the increasing diffusion of the solute through a concomitant increase in particle size.The values for the wettability were from 10.00 to 15.00 g/min. Borges et al. (2002) found a value for the wettability of the powdered passion fruit juice of 0.192 g/min, less than the values found for the tomato powder. This property was improved by increasing the maltodextrin concentration (Bhandari et al., 1993) and by increasing the air exit temperature (Borges et al., 2002).

The value for the product consistency varied from 19.5 to 21.5 cm and also suffered no significant influence from the variables under study. The results showed that the Bostwick values for the reconstituted powder were higher than those of tomato pulp with the same concentration of the soluble solids (1.9 cm), that is, less consistent, showing greater leakage in the consistometer. A significant change in the consistency characteristics occurred, in agreement with Thakur et al. (1996), who observed that the processing caused a higher reduction in the viscosity as compared to the raw mashed tomato. This was partially caused by the heat or enzymatic degradation of the pectin. Henig and Manheim (1971) found tomato powder consistency values from 15.3 to 23.0, similar to the values found in this study.

Table 2 - Reconstituition properties and colour.

Assay	MC	SOL.	WET.	CON.	a*/b*	L
+X1 +X2 -X3	4.00	21.97	12.00	19.50	1.00	57.98
-X1 +X2 -X3	6.80	20.39	10.00	21.00	1.16	57.32
+X1 - X2 - X3	6.60	19.82	12.00	19.50	0.97	43.80
-X1 -X2 - X3	5.50	21.00	15.00	21.50	0.98	78.76
+X1 +X2 +X3	5.50	22.00	12.00	19.50	0.98	50.97
-X1 +X2 +X3	6,00	17.65	15.00	19.50	1.01	62.37
+X1 -X2 +X3	5.54	25.62	12.00	19.50	0.95	37.56
- X1 -X2 +X3	5.78	19.49	12.00	19.50	0.96	40.88
0X1 0X2 0X3	5.32	26.00	15.00	20.0	0.97	48.42
0X1 0X2 0X3	5.94	24.75	15.00	20.0	0.98	48.45
0X1 0X2 0X3	5.67	26.73	15.00	20.0	0.97	48.39

* significant at $p < 0.05$, MC – Moisture content (g/100g), SOL – solubility (g/100g), WET – wettability (g/min), CON – consistency (cm), a*/b* - colour index L – lightness.

Table 3 - Estimates of the effect on the reconstitution properties and colour

Factor	MC.	SOL.	WET.	CON.	a*/b*	L
Mean/Int.	5.70	22.27	13.18	19.95	0.99	49.50
X1	-0.06	2.68	-1.00	-0.88	-0.36*	-4.80*
X2	-0.28	-1.13	-0.50	-0.13	0.56*	14.40*
X3	-0.02	0.54	0.50	-0.87	-0.37*	-4.00*
X1*X2	-1.04	0.09	0.50	0.12	-0.29*	-0.60*
X1*X3	0.24	2.67	-0.50	0.88	0.02*	-2.60*
X2* X3	0.37	-1.65	2.00	0.12	-0.02*	3.00*
X1*X2*X3	0.91	-1.04	-2.00	-0.13	0.02*	3.40*

* significant at $p < 0.05$, MC – Moisture content (g/100g), SOL – solubility (g/100g), WET – wettability (g/min), CON – consistency (cm), a*/b* - colour index L – lightness.

The values for the colour index were in the range from 0.9595 to 1.1677, considering that the inlet drying air temperature and the atomisation speed showed significant effects on this property. These relations could be expressed by equations 1 and 2, considering X3=0 and X2=0, respectively, giving a good fit with the experimental data (R^2=0.9358 for the two equations).

IC=0.9938 – 0.01796*X1 + 0.02781*X2 - 0.01426*X1*X2 (1)

IC=0.9938 - 0,0179625*X1 - 0.01873*X3 + 0.0102375*X1*X3 (2)

These models are represented by Fig. 1 and 2, respectively.

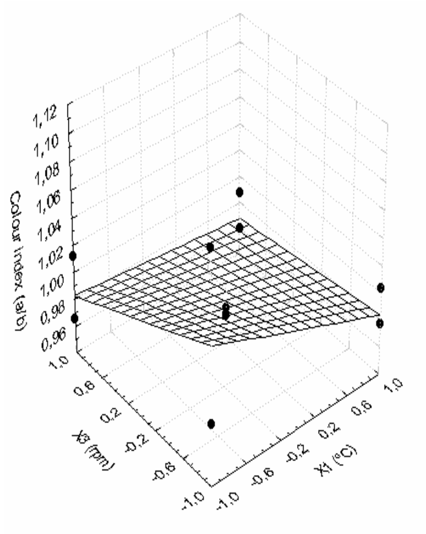

Figure 1 - Colour index for tomato powder obtained for X3=0.

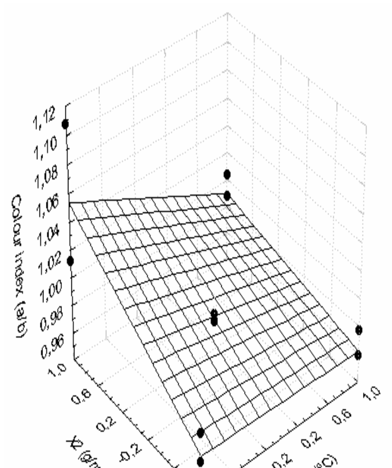

Figure 2 - Colour index for tomato powder obtained with X2=0.

The a/b colour index for the tomato powder increased with decrease in the inlet temperature (Fig. 1) and with decrease in atomisation speed (Fig. 2). According to Shi et al (1999) the colour retention in the tomato products was better at low temperatures, and these authors found values for the a*/b colour index of the dehydrated tomato to the order of 1, 2, a value close to that found in the current study. Anguelova and Wathersen (2000) found a loss of 30 to 40% of lycopene in the spray dried tomato powder, this being the main pigment responsible for the red colour of the product. They attributed this loss to the oxidation of the product due to the use of high temperatures. Goula and Adamapoulos (2005b), using lower inlet air temperatures (110-140°C), found a loss of 9 to

16%. Francisconi et al (2003) also observed a fall in the a* and b* values for the powdered passion fruit juice at higher atomisation speeds, because higher atomisation speeds produced smaller particles, which, when exposed to heat, tened to intensify the oxidation.

Lightness was also affected by the atomisation speed and inlet temperature, these relations being expressed by equations 3 and 4, considering X3=0 and X1=0, respectively, which had a good fit with the experimental data (R^2=0.99 for the two equations).

$$L=49.536363-2.3775*X1+7.205*X2 - 0.3075*X1*X2 \quad (3)$$

$$L=49.53636 - 2.3775*X1 - 2.01*X3 - 1.3025*X1*X3 \quad (4)$$

These models were represented by Fig. 3 and 4, respectively, and indicated that increasing the atomisation speed and the inlet temperature cause an increase in the L values, resulting in a lighter product, this also being due to the pigment oxidation, as previously discussed. Francisconi et al. (2003) and Abadio et al. (2004) also observed higher lightness for the dehydrated fruits with increasing atomisation speed. Shi et al. (1999) found an L value for the dehydrated tomato in the range of 38, 40, smaller than the values found in this work.

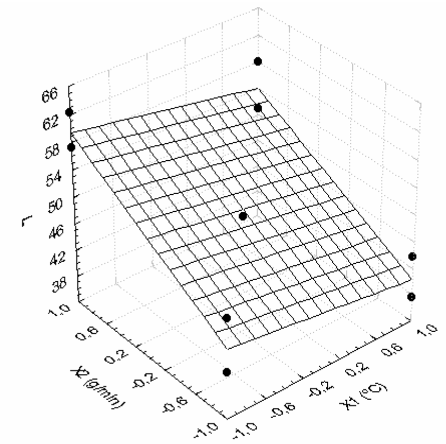

Figure 3 - L Coordinates for tomato powder obtained with X3=0.

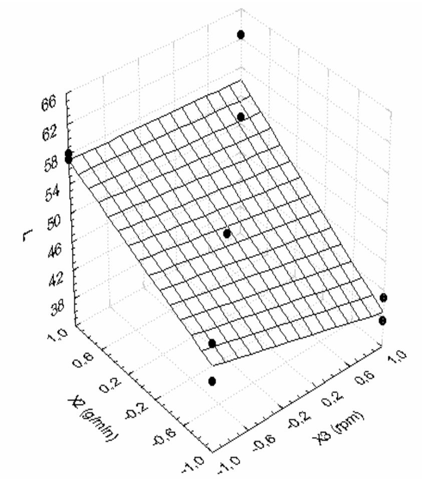

Figure 4 - L Coordinates for tomato powder obtained with X1=0.

In order to preserve the tomato powder colour and good reconstitution properties, the use of an atomisation speed of 25,000 rpm and an inlet temperature of 200°C is recommended.

ACKNOWLEDGMENTS

We thank to FAPERJ for financial support in the restoration of the spray dryer and also to Food Karambi, Corn Products Brazil and Arinos Chemistry for supplying the raw material and additives.

RESUMO

Tomate em pó foi produzido por secagem por atomização da polpa de tomate. Um planejamento fatorial completo 2^3 com ponto central foi conduzido variando a taxa de alimentação (127-276 g/min), temperatura de entrada do ar (200-220^o C) e a velocidade de atomização (25000-35000 rpm). As respostas analisadas foram: conteúdo de umidade, solubilidade, molhabilidade, consistência e cor, ma os fatores somente afetaram significativamente a cor. Todas as amostras tornaram significantemente mais escuras e menos vermelhas com o aumento das variáveis sob estudo. Baixa velocidade de atomização (25000 rpm) e menor temperatura do ar de secagem (220^o C) produziram pós de maior índice de cor (a/b) e menor escurecimento.

REFERENCES

Abadio, F. D. B; Domingues, A .M.;. Borges, S.V.and Oliveira, V. A. (2004),Physical properties of powdered pineapple (Ananas comosus) juice-Effect of malt dextrin concentration and atomization speed. *Journal of Food Engineering*, **64**, 285-287.

Al Asheh, S.; Jumah, R.; Banat, F. and Hammad, S. (2003), The use of experimental factorial design for analysing the effect of spray dryer operating variables on the production of tomato powder. *Transactions of the Institute of Chemical Engineers*, **81**, 81-88.

Alpari, A .(1974), Changes in the quality characteristics of tomato purée during spray drying. *Acta Alimentaria*, **5**, 303-311.

Anguelova, T. and Warthsen, J. (2000), Lycopene stability in tomato powders. *Journal of Food Science* **65**, 67–70.

Barros Neto, B.; Scarmínio, I. S. and Bruns, R. E. (1995), Planejamento e otimização de experimentos. Campinas, UNICAMP, pp.299.

Borges, S.V.; Reis, A. L. S. H.; Jorge, E. C.; Pinto, P. R. and Oliveira, V. M. (2002), Jugo de frutas tropicales deshidratados por spray drying. *Alimentaria*, **334**, 125-130.

Bhandari, B.R.; Senoussi, A.; Dumoulin, E.D.and Lebert, A. (1993), Spray drying of concentrated fruit juices. *Drying Technology*, **1**, 1081-1092.

Cai, Y.Z.and Corke, H. (2000), Production and properties of spray-dried *amaranthus* betacyanin pigments. *Journal of Food Science*, **65**, 1248-1252

Desobry, S. A ; Netto, F.M. andLabuza, T.P. (1997), Comparison of spray-drying, drum-drying and freeze-drying for β-carotene encapsulation and preservation. *Journal of Food Science*, **62**, 1158-1162.

Francisconi, A .D.; Campos, F. R.; Pereira, D.B.; Oliveira, V. M.; Borges, S. V. and Gay, J. (2003),Propiedades físicas del jugo de maracuyá en polvo- Efecto de la velocidad de atomización y concentración de maltodextrina. *Alimentaria*, **346**, 97-100.

Henig, Y. and Manheim, C. H. (1971) Drum dying of tomato concentrate. *Food Technology*. **25**, 59-62

Instituto de Adolfo Lutz. (1977), *Normas Analíticas: métodos físicos y químicos para análise de alimentos***.** São Paulo, IAL.

Giovanelli, G., Lavelli, V., Peri, C. and Nobili, S. (1999), Variation in antioxidant compounds of tomato during vine and post-harvest ripening. *Journal of the Science of Food and Agriculture*, **79**, 1583–1588.

Goula, A. M. and Adamopoulos, K. G. (2005 a), Spray drying of tomato pulp in dehumidified air: II. The effect on powder properties. *Journal of Food Engineering*, **66**, 35-42.

Goula, A. M. and Adamopoulos, K. G. (2005 b), Stability of lycopene during spray drying of tomato pulp. *Lebensmittel Wissenchaft und Technology*, **38**, 479-487.

Hall, G.M.and Iglesias, A. (1997), Functional properties of dried milk whey. *Food Science and Technology International*, **3**, 381-83.

Jorge, E. C.; Oliveira, V. M. And Borges, S.V. (2003), Empleo de un secador por atomizacion a escala piloto en la produción de maracuyá en polvo y su aceptabilidad para elaborar jugo reconstituido. *Alimentaria*, **342**, 83-86.

Kalil, M. A and Sial, M. B. (1974), Spray drying of mango juice powder. Mesopotamia *Journal of Agriculture*, **9**, 47-56.

King, C.J.; Kieckbusch, T.G and Greenwald, C.G. (1984), Food quality factors in spray drying. In: Mujundar, A.S. *Advantages in drying*. vol.3, pp. 71-120, Washington, Hemisphere Publishing Co.

Leonardi, C., Ambrosino, P., Esposito, F. and Fogliano, V. (2000), Antioxidant activity and carotenoid and tomatine contents in different typologies of fresh ‘consumption tomatoes**.** *Journal of Agricultural and Food Chemistry*, **48**, 4723-4727.

Madhavi, D.L. and Salunkhe, D.K. (1998), Tomato. Handbook of vegetable science and technology. In: Salunkhe, D.K. And Kadam, S.S., Editors, 1998, *Production, Composition, Storage, and Processing*, Marcel Dekker, New York, (chapter 7), pp. 171–201.

Nath, S.and Sapathy, G.R. (1998), A sistematic approach for investigation of spray drying process. *Drying technology*, **16**, 1173-1193.

Maia, A ., B.R. A.and Golgher, M. (1983), Parâmetros para avaliação da qualidade de reconstituição do leite em pó desidratado. *Boletim da SBCTA*, **17**, 235-254.

Masters, K. (1991) Spray Drying Handbook, 5th ed. London, Longman Scientific and Technical.

Nguyen, M.L. and Schwartz, S.J. (1999). Lycopene: chemical and biological properties. *Food Technology*, **53**, 2.

Papadakis. S. E, Gardeli. C. and Tzia, C. (1998), Raizin Extract Powder: Production, Physical and Sensory Properties. In: *Proceeding of the 11th International Drying Symposium ID's 98*, Haldiki:Ziti Editions.

Perez-Munoz, F.and Flores, R.A. (1997), Characterization of a spray drying system for soy milk. *Drying Technology*, **15**, 1023-1043.

Pisecky, J. (1978), Bulk density of milk powders. *Dairy Industries International,* 2, 4-11.

Shi, J.; Le Maguer, M., Kakuda, Y., Liptay, A. and Niekamp, F. (1999). Lycopene degradation and isomerization in tomato dehydratation, *Food reserch International***, 32**, 15-25.

Shi, J. and Le Maguer, M. (2000), Lycopene in tomatoes chemical and physical properties affected by food processing. *Critical Reviews in Food Science and Nutrition*, **40**, 1–42.

Thakur, B.R., Singh, R.K.and Nelson, P.E. (1996), Quality attributes of processed tomato products: a review. *Food Review International*, **12**, 375–401.

Walton, D.E. (2000), The Morphology of spray dried particles- a qualitative view. *Drying Technology*, **18**, 1943-1986.

Received: May 12, 2006;
Revised: March 29, 2007;
Accepted: March 24, 2008.